MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support

Outfall from the As Samra wastewater treatment plant

CHARACTERIZATION OF WASTEWATER EFFLUENT IN THE AMMAN-ZARQA BASIN

WATER REUSE COMPONENT

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EXECUTIVE SUMMARY

This document presents the results of an investigation of the effluent being discharged into the Amman-Zarqa Basin, covering past and potential future characteristics in terms of quantity and quality. The focus is on the point of discharge of effluent; the conveyance, storage, blending and use of effluent from the Amman-Zarqa Basin will be considered in other reports.

There are four wastewater treatment facilities, Abu Nuseir, As Samra, Baq'a and Jerash (East), presently located in the Basin, while a further two, Jerash (West) and Zarqa, are planned.

Relevant data and information were gathered from the Ministry of Water and Irrigation, the Water Authority of Jordan (WAJ), the Royal Scientific Society (RSS), the treatment facilities, and other sources. The investigation and analysis of the data and information included numerous discussions with the Ministry of Water and Irrigation (MWI) personnel and team members of the Japanese International Cooperation Agency (JICA).

Quantities

In addition to previous studies and to this investigation, three major efforts are currently being undertaken which involve establishing estimates of future effluent quantities from Jordanian wastewater treatment plants, including those in the Amman-Zarqa basin. These efforts are the Water Resources Masterplan (JICA, 2000), the National Water Sector Review (World Bank, 2000), and the development of the Wastewater Module of the Ministry of Water and Irrigation. All of these efforts utilize a population-based methodology to determine the expected volumes of effluent. This methodology, along with the parameters used by the World Bank (World Bank, 2000) and subsequently JICA (JICA, 2000), was also used in this investigation.

In addition to considering the population-based projections, this investigation examined the historical trends in the volume of effluent generated at each plant. Projections based on the linear regression of the historical data were generally lower than the population-based projections; for example, at As Samara, the projection of the historical effluent records were 10 percent lower at the planning horizon year 2025. Typically this difference was due to the fact that the historical trends included diminishing water supply per capita, which is expected to be reversed in the next five to ten years.

The gross volume of effluent discharged into the Zarqa wadi system is dominated (93 percent) and will continue to be dominated (90 percent by year 2025) by the As Samra-Zarqa treatment facilities.

The cumulative projections for all effluent discharged into the Amman-Zarqa basin using the population based analysis is shown in Figure 1 and Table 1.

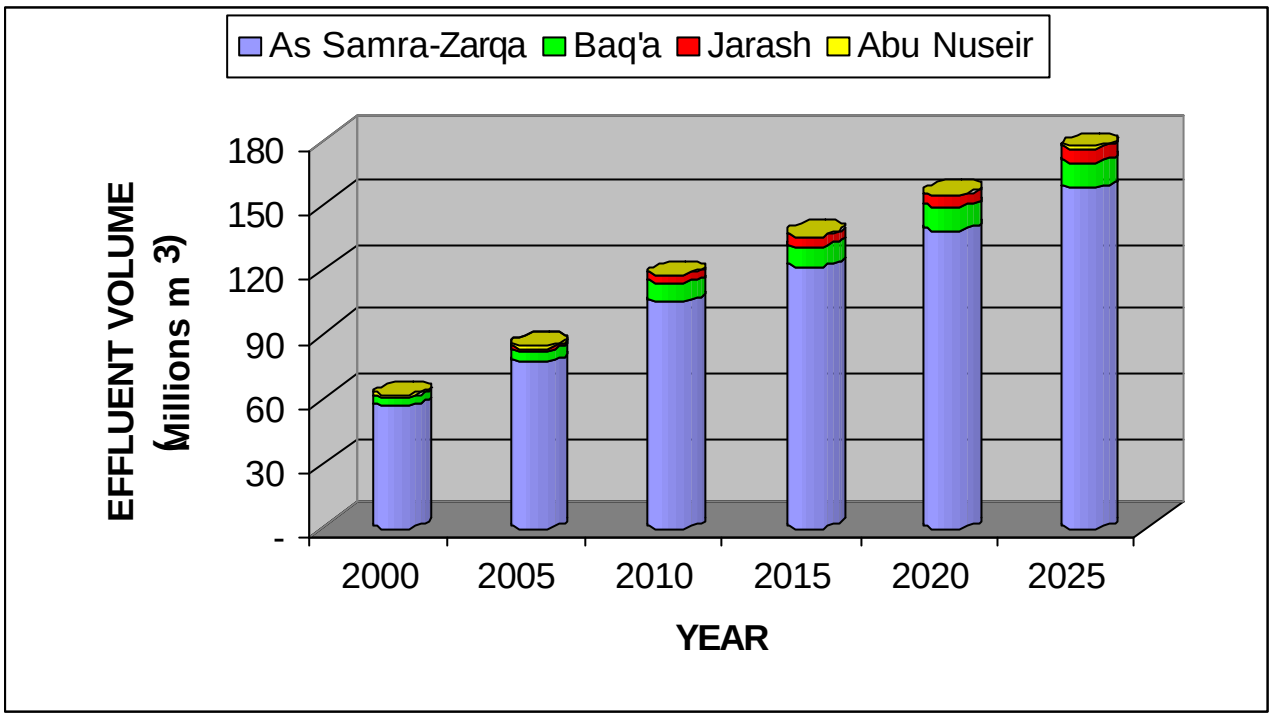


Figure 1. Projection of total effluent (MCM annual flow) to be discharged to the Amman-Zarqa Basin

The increased rate of effluent production between years 2005 and 2010 is due to the expected increase in per capita water supply.

Table 1. Projection of total effluent (MCM annual flow) to be discharged to the Amman-Zarqa basin

TREATMENT PLANT	2000	2005	2010	2015	2020	2025
As Samra-Zarqa	56.2	77.0	104.7	120.7	137.9	157.6
Jerash	0.6	1.3	3.9	4.5	5.0	5.8
Abu Nuseir	0.5	0.5	0.6	0.7	0.7	0.8
Baq'a	3.8	5.3	8.4	9.7	10.9	12.4
TOTAL	**61.1**	**84.1**	**117.6**	**135.6**	**154.6**	**176.6**

The projections for effluent generated are based on per capita water suppy rising by 29 percent in the next five to ten years, and meeting the needs of an expanding population. This requires relatively aggressive development of new water sources. In the event that one or more of these new developments is delayed, it is possible that the water supply targets will not be met. In such a case, the actual wastewater effuent volumes in the future are more

likely to match the linear projections based on the historical effluent volumes. This is about 15 percent less than the anticipated volume. This difference will be considered in the sensitivity analysis for overall basin management.

Qualities

Data on the quality of the effluent from the wastewater treatment plants were obtained from the Water Authority of Jordan (WAJ) and the Royal Scientific Society (RSS). The RSS data set is directly relevant to the As Samra plant only. The WAJ data set covers all the plants, but is much less comprehensive for the minor facilities than for As Samra.

The WAJ data sets, with the exception of boron at As Samra, do not regularly include trace elements and heavy metal levels. Some one-off samples were however made available. RSS did have trace element and heavy metal values, but only for 1999.

For each treatment facility, where data were available, this investigation tabulated the actual value of each quality parameter along with the relevant Jordanian Standard and the expected value of the parameter in the future.

In the case of As Samra the levels of trace elements and heavy metals in the effluent are much lower than those specified by the standards. With the exception of Zinc and Boron, the standards are as stringent as the United States Environmental Protection Agency (EPA, 1992) water reuse guidelines. Other parameters, however, are not in compliance with the respective Jordanian Standards. These are: BOD_5; COD; TSS; FOG (fats, oils & greases); NH_4^+ - N; Total Nitrogen; PO_4^- - P; Cl^-; HCO_3^-; and fecal coliforms. Except for PO_4^- - P, the planned improvements at As Samra are expected to address these parameters, reducing them to at least the Jordanian Standards and, most likely, below. The specifications for the BOD_5 and TSS As Samara will be specifically more stringent than the Jordanian standards, at 30-mg/l.

At Jerash (East) site, CL, SO_4, and HCO_3 are not recorded regularly. The records for NO_3-N, NH_4-N, PO_4-P, B and TFCC are sparse, and those that do exist suggest that none of these parameters are in compliance with the Jordanian standards. Single readings were observed in September 1999 for Cu, Fe, Mn, Cd and Zn. Fe, Mn and Zn were well within the Jordanian Standards, and Cd was at the standard. However, Cu was not in compliance. BOD_5, COD, DO, TDS, TSS and PH are all in compliance with the Jordanian standards. There are no plans for further development of the wastewater treatment facility at Jerash (East); therefore, there should be no major changes in the quality parameters. Although the total contribution of Jerash to the Amman-Zarqa basin is relatively small, the non-compliance of certain parameters is of concern, particularly as most of the present effluent stream is being used for irrigated agriculture nearby.

In the case of Abu Nuseir the Water Authority of Jordan (WAJ) monitors BOD_5, COD, DO, TDS, TSS and PH. All are in compliance with the Jordanian Standards. As the rate of influent increase at Abu Nusier is expected to be relatively low, and the present plant has the capacity to treat projected influent loads through the planning horizon, it is expected that quality parameters will not deteriorate. A one-off sampling program should be contracted for other parameters prior to using this effluent for reuse.

With Baq'a, the Water Authority of Jordan (WAJ) monitors BOD_5, COD, TDS, and TSS. Despite the Baq'a facility being relatively effective at lowering the values of the monitored parameters in the influent, only the TDS (Total Dissolved Solids) in the effluent complies with the Jordanian Standards for discharge to wadis. The present facility is overloaded (WAJ, 2000). The new plant, which uses trickling filters, will be completed in the last quarter of this year (2000). In the near future, a conservative assumption would be that the parameters are in compliance with the Jordanian Standards and, as with As Samra, the Total Nitrogen is at or below 30-mg/l. Prior to proceeding with reuse options using Baq'a effluent it would be prudent to determine the levels of the other parameters, trace elements and heavy metals.

I. INTRODUCTION

This document reports on the work associated with water reuse activity 4.1, the characterization of wastewater effluent in the Amman-Zarqa basin. The characterization includes the analysis and determination of the quantity and quality of the treated effluent that is presently discharged into the wadi, and what it is likely to be in the future.

The activity included compiling existing data and information on current and projected quantities and qualities of effluent, and using these to determine the likely quantities and qualities of effluent discharged to the Zarqa wadi system.

This document is limited to characterizing present and projected effluent discharges from the wastewater treatment plants in the Amman-Zarqa basin. The characterization of the water quality downstream of these plants, through the King Talal Reservoir (KTR) and into the Jordan Valley will be presented in a separate document (see Grabow, 2000 for preliminary information).

II. MAPPING & LOCATION

Presently there are four wastewater treatment plants which discharge effluents into the Wadi Zarqa system. These are As Samra, Jerash (east), Baq'a, and Abu Nuseir, as shown in Figure II.1. In addition, two further facilities are planned, namely Zarqa and Jerash (west). All of the effluent from these plants, including those planned, eventually reaches King Talal Reservoir, where it is stored along with surface runoff until it is needed in the Jordan Valley.

There are a number of gaging stations and water quality sampling stations within the Amman-Zarqa basin, as shown in Figure II.2. In addition, the Water Authority of Jordan (WAJ) monitors the effluent from (and within) each of the facilities. The sites with an "AL" prefix are surface water gaging sites administered by the Ministry of Water and Irrigation (MWI). Those sites numbered 1 through 7 are water quality sampling sites used by the Royal Scientific Society (RSS) for the contract with WAJ, and sites 100 through 700 (note, 700 is further downstream in the Jordan Valley) are water quality sampling sites used by the Royal Scientific Society (RSS) for the contract with the Jordan Valley Authority (JVA). For this document, the sites of interest are site 4 (at the As Samra outlet), and the WAJ data from each of the four wastewater treatment facilities.

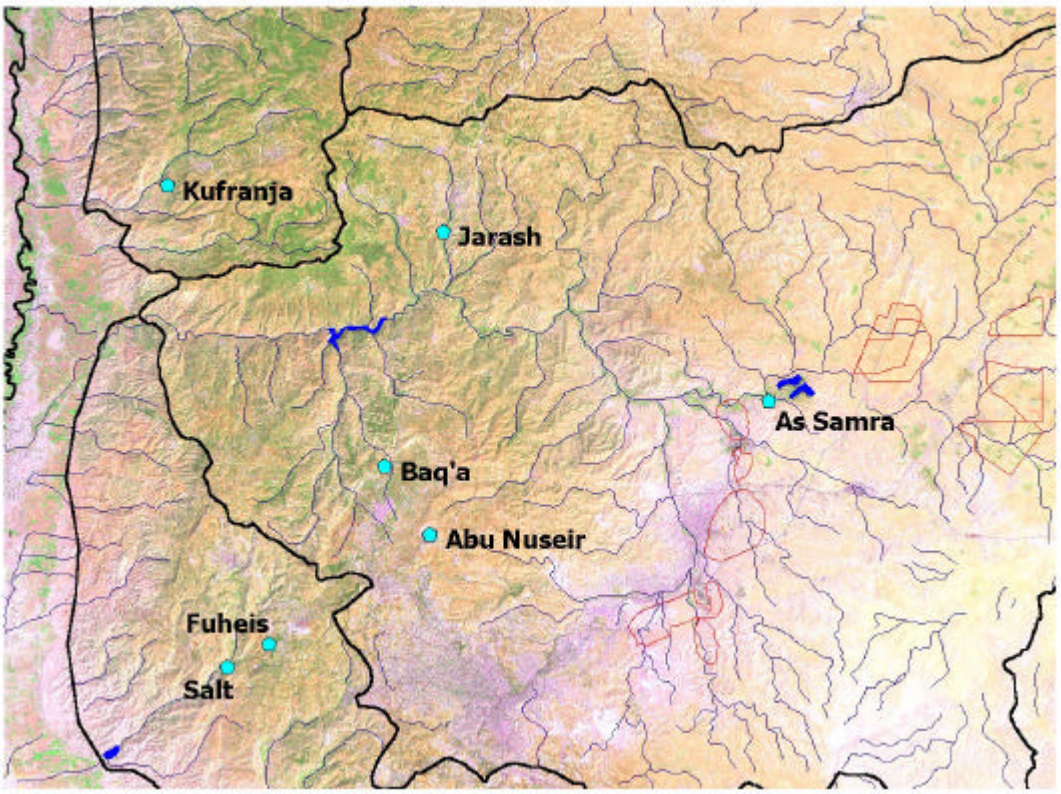


Figure II.1. Locations of the wastewater treatment plants in the Amman-Zarqa basin.

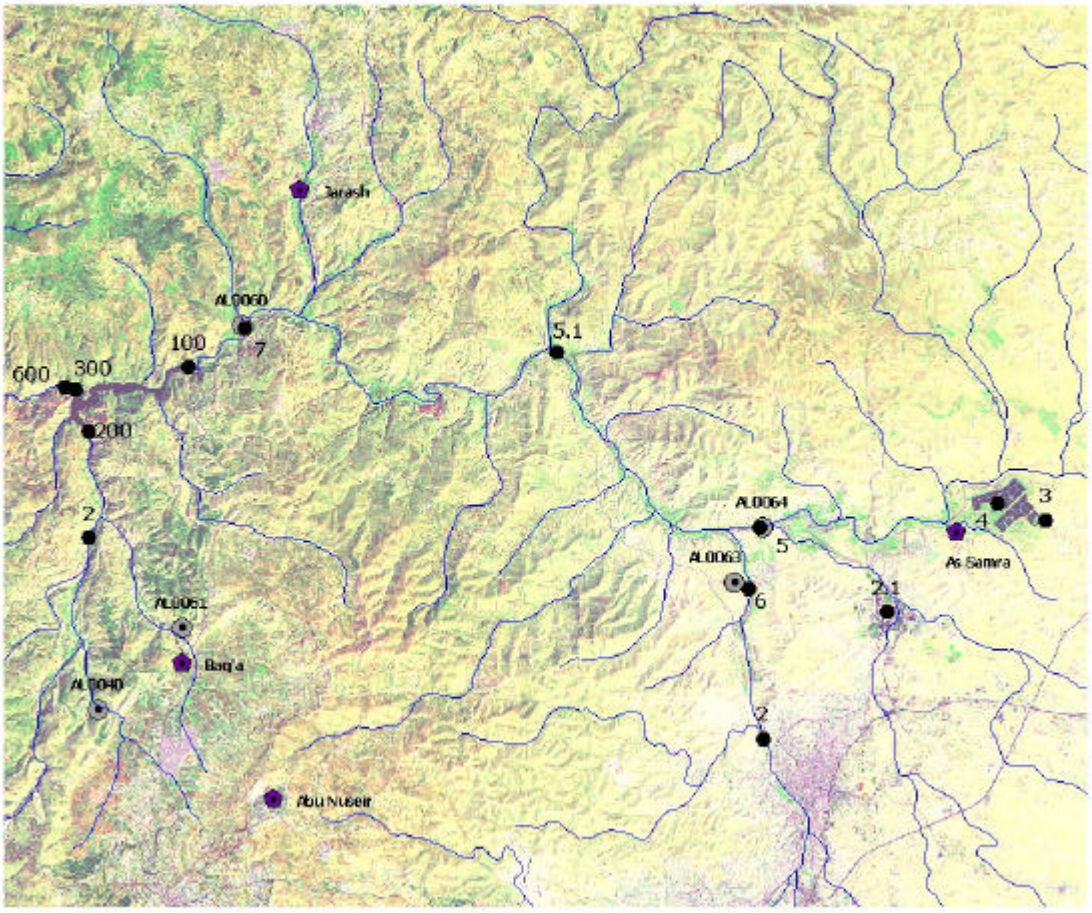


Figure II.2. Gaging and sampling stations in the Amman-Zarqa basin.

III. EXISTING INFORMATION

Key documents and information sources for this study are the annual report from the Water Authority of Jordan (WAJ), and the annual study reports from the Royal Scientific Society (RSS).

A number of studies have been conducted on aspects of wastewater effluent discharged into the Wadi Zarqa, particularly for As Samra. Harza (1997) is the most recent rigorous attempt at projecting the quantity from As Samra. However, this study does not account for the other three plants. The World Bank (World Bank, 1997) also estimates the effluent quantities from the wastewater treatment plants in Jordan.

In addition, major efforts being undertaken concurrent to this investigation have generated estimates of future effluent quantities at the Jordanian wastewater treatment plants, including those in the Amman-Zarqa basin. These efforts are the Water Resources Masterplan (JICA, 2000), the National Water Sector Review (World Bank, 2000), and the development of the Wastewater Module of the Ministry of Water and Irrigation. As will be detailed later, all three of these efforts are inter-related in that they use the same general methodology and database.

IV. ASAMRA & ZARQA WASTEWATER TREATMENT PLANTS

The characterization of present and future treated wastewater considers both the quantity and quality of effluent from the As Samra wastewater treatment plant. A further wastewater treatment plant is planned for Zarqa (Harza, 1997), which would eventually treat part of the sewage load from Amman and Zarqa. For this analysis, it is assumed that wastewater loads that come from Ain Ghazal and from Zarqa will continue to be treated at As Samra. In the context of this study, "As Samara" includes the existing plant, future modification to the existing plant, and any future plant such as the "Zarqa" plant.

IV.1. QUANTITY OF EFFLUENT

Concurrent to this work, both JICA (JICA, 2000) and the World Bank were interested in determining the projected quantity of effluent from wastewater treatment plants in Jordan, including those within the Amman-Zarqa basin. The final results of the World Bank investigations were not available at the time of writing; however, the spreadsheets used, and the subsequent adaptations by JICA (JICA, 2000) were made available. As this characterization progressed there was significant cooperation between the team, the Ministry of Water and Irrigation, and JICA. This synergy contributed to further rationalization of the projections, and resulted in a number of refinements to the final projections reported herein.

As discussed above, the wastewater treatment facility at As Samra will be improved by year 2007. The actual design of the plant is yet to be determined. It is expected that the treatment will be some form of mechanical process, probably activated sludge, and, possibly, with the present ponds being adapted to polishing ponds (WAJ, 2000). It can be concluded that the quantity of water losses, to evaporation and infiltration, will be reduced when the new facilities are commissioned. With this in mind, the analysis presented here uses the historic and projected influent, and then adjusts these values for the actual and expected losses in the facility.

IV.1.1. Projection of Historical Influent Data (Method 1)

The historic data for the quantity of wastewater entering the plant were obtained from the Water Authority of Jordan (WAJ). This data set comprised monthly inflow quantities of wastewater entering the As Samra treatment plant from August 1985 through December 1999. These data are shown in Figure IV.1.

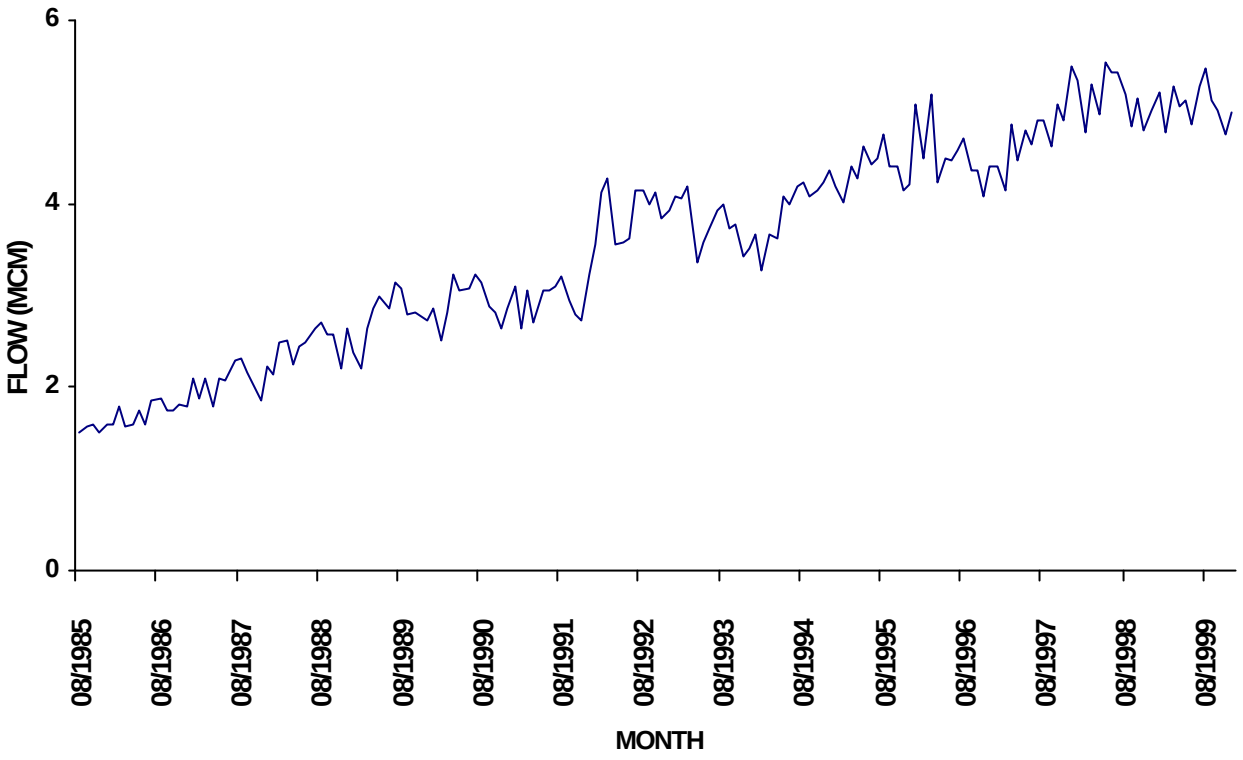


Figure IV.1. As Samra Monthly Inflow (1985-1999)

Using the above data, annual historical inflow quantities were generated (see Figure IV.2.) and, by regression, projections of expected annual inflow quantities through the planning horizon (year 2025), were made, the results of which are shown in Figure IV.3. and Table IV.1.

As discussed earlier, the forecast will exceed the treatment capacity of the new facility being developed at As Samra. The future expansion in capacity could come from either the planned Wadi Zarqa plant (Harza, 1997) or from a further expansion of the plant at As Samra.

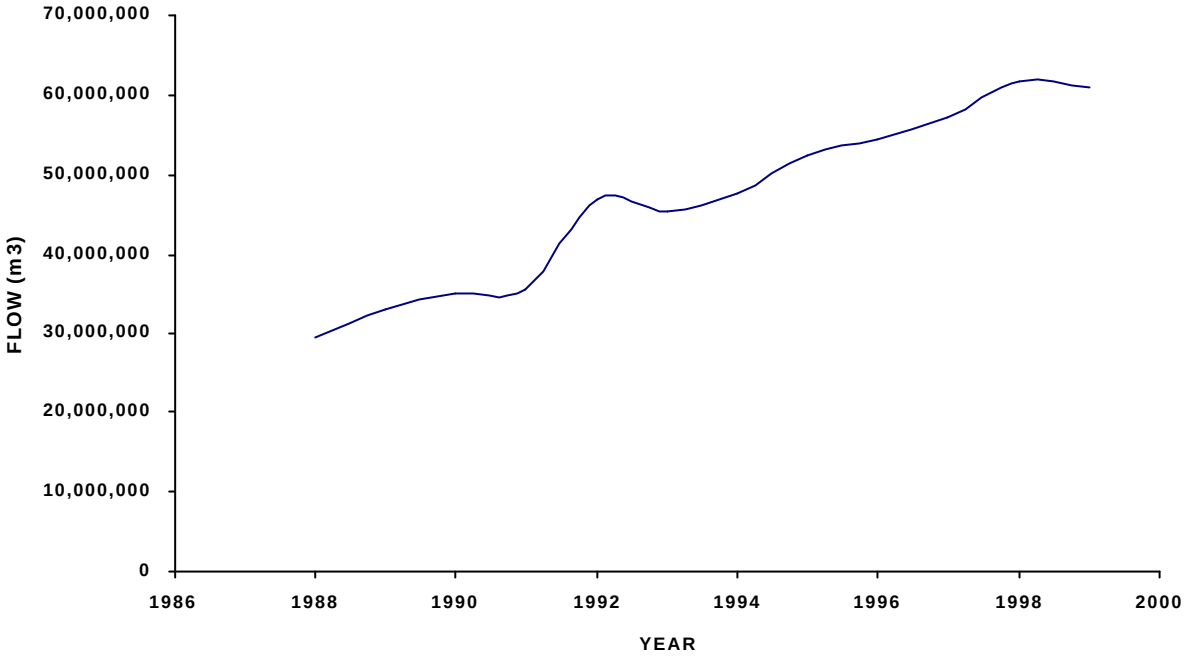


Figure IV.2. As Samra historical annual inflows

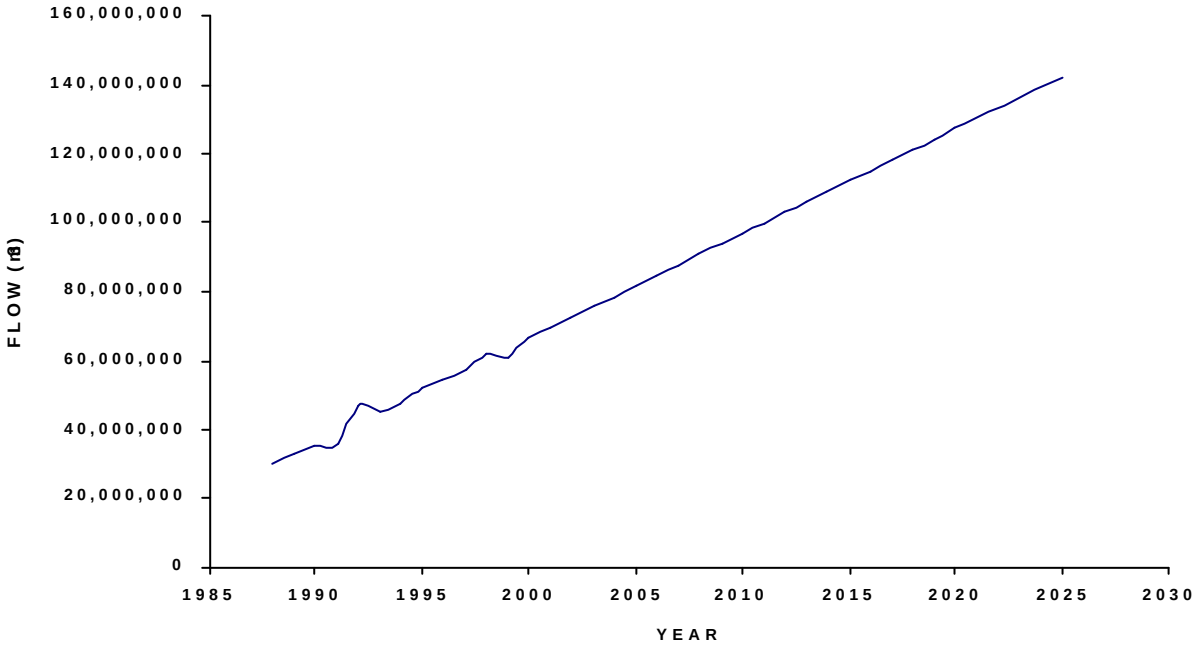
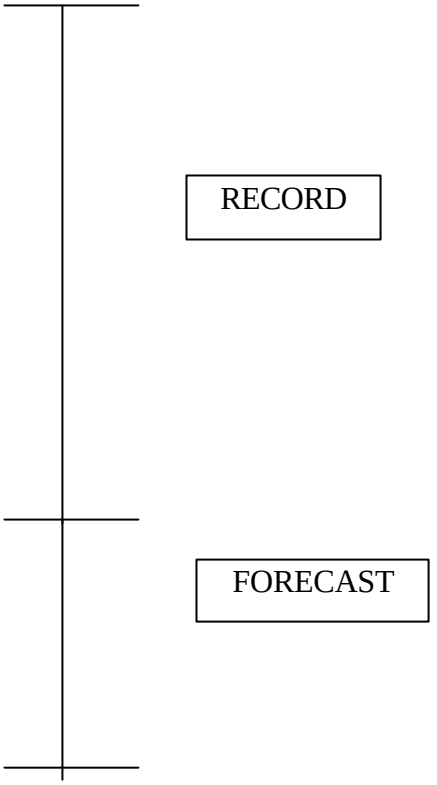


Figure IV.3. Projected annual inflow to As Samra

Table IV.1. Projected annual inflow to As Samra

YEAR	INFLUENT (m^3)
1988	29,691,286
1989	33,223,785
1990	35,122,831
1991	35,694,670
1992	46,851,682
1993	45,363,000
1994	47,553,204
1995	52,356,145
1996	54,470,304
1997	57,242,251
1998	61,800,247
1999	60,896,753
2000	66,413,074
2005	81,585,556
2010	96,758,039
2015	111,930,521
2020	127,103,004
2025	142,275,486



IV.1.2. Projection of Influent Based on Population Growth (Method 2)

Harza (1997), the World Bank (2000) and JICA (2000) used the same basic methodology for estimating the influent into As Samra and, as planned, the Zarqa wastewater treatment facilities. This methodology uses projections of the population and per-capita water supplied, and estimates of the coverage percentage and return factors. The analysis conducted by JICA (2000) is the most recent, has built on that of the World Bank and has been refined with input from the ARD-MWI team.

From year 2005 to 2010 the per-capita water supply in the service area is projected to increase from 100-l/p/d to 129-l/p/d, reflecting the development of new water supplies for the service area. The per-capita water supply is projected to remain at 129-l/p/d thereafter through the planning horizon (2025). The population is expected to increase at 3.1 percent per year through 2010, 2.9 percent through 2015, and 2.7 percent through the planning horizon. In addition, the town of Al Sukhnah, which is presently not connected to the As Samra facility, is expected to be sewered and connected by the year 2010.

The projected annual influent flows, developed from the above methodology, are shown in Table IV.2. and Figure IV.4. For comparison, the results from the projection of historical influent data (method 1) are also shown in Figure IV.4.

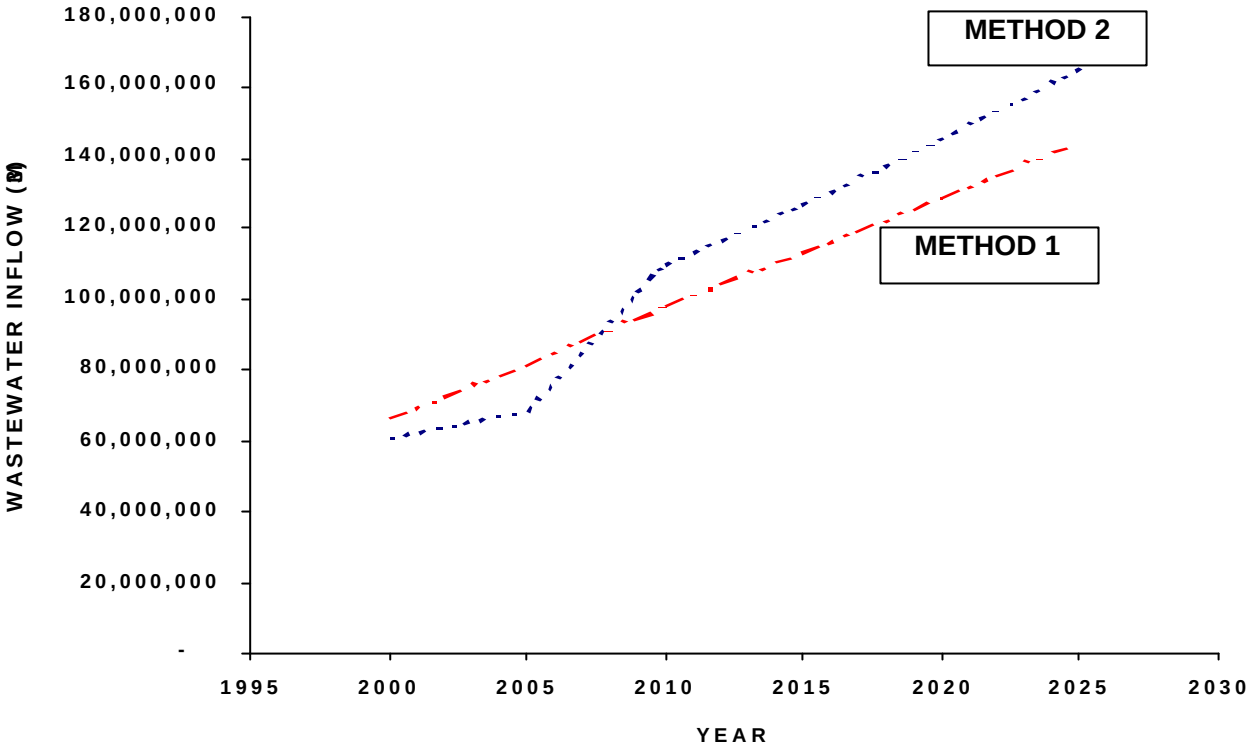


Figure IV.4. Projections of influent to As Samra

Table IV.2. Projection (Method 2) of influent to As Samra

YEAR	INFLUENT (M^3)
2000	61,319,368
2005	68,883,677
2010	110,174,411
2015	127,103,530
2020	145,214,448
2025	165,905,982

Other than for the period between 2005 and 2010, the slopes of the two projections are similar. The steep increase in the influent levels in the second projection is due to the anticipated increase in water supplies and, to a much lesser extent, the connection of Al Sukhnah. The population-based projections (method 2) are approximately 13.5 M-m^3 (9.5 %) higher than that from the projection of the historical influent data (method 1).

Assuming that a 29 percent increase in per-capita water supply results in a similar increase in influent at the treatment facilities between year 2005 and 2010, and adding in Al Sukhnah at the same period, the projection of the historical influent data (method 1) was modified. These results, which by 2025 are over 12 percent higher than the population based projections, are shown in Figure IV.5. and in Table IV.3. Note that a 29 percent increase in

water supply per capita, along with meeting the needs of an expanded population, requires aggressive development of new water sources. This will be discussed further in section Chapter VI.3.

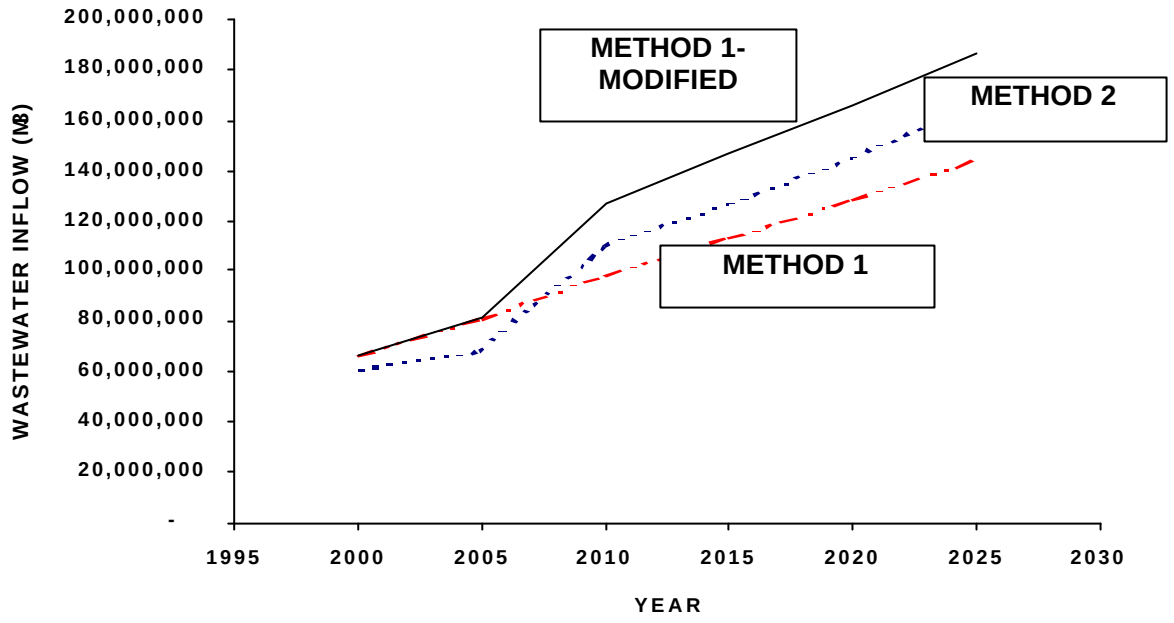


Figure IV.5. Projected Annual Influent Volumes

Table IV.3. Comparison of projections of influent to As Samra

YEAR	METHOD 2 (m^3)	METHOD 1 (m^3)*	METHOD 1 – MODIFIED (m^3)
2000	61,319,368	66,413,074	66,413,074
2005	68,883,677	81,585,556	81,585,556
2010	110,174,411	98,248,954	126,741,150
2015	127,103,530	113,650,526	146,609,179
2020	145,214,448	129,068,091	166,497,837
2025	165,905,982	144,520,578	186,431,546

* Including Al Sukhnah town (Estimated using JICA's values)

From the above, it can be concluded that the population-based projection of influent (Method 2) is reasonable. However, as discussed in the text box below, the difference in predicted influent loads in the year 2000 would suggest that the parameters used in the population-based projections need adjusting. Details are provided below.

Population based influent loads are determined as follows:

$$I = P.C.R.S.(1 - L)$$

where I = influent volume (m^3/annum)
P = population in service area
C = coverage or connected households
R = return factor
S = water supply (l/c/d)
L = losses (or inflow)

For the World Bank scenario, at year 2000 the water supply [S] is taken as 108-l/c/d and the population in the service [P] area as 1,922,555. From projection of the actual influent data, the quantity of influent [I] expected in year 2000 is 66,413,074 (m^3). From this, the product of C , R and L is 0.876, whereas the product of the three parameters used in the population based projections was 0.809. This is an 8 percent difference.

From the above, the population based projections would seem to be under-estimating either the coverage, the return factor or the contribution of inflow into the sewer system, assuming the population and the water supply are correct.

IV.1.3. Projection of Effluent

As mentioned above, the losses in the waste stabilization ponds of the present As Samra wastewater treatment plant are higher than are expected within the facility in the future, which will likely be based on mechanical plant. Using the historical data for the influent and effluent (WAJ, 2000) at As Samra, the average losses were determined (see Table IV.4).

Table IV.4. Historical Losses at As Samra

YEAR	ANNUAL INFLOW (m^3)	ANNUAL OUTFLOW (m^3)	% LOSSES
1988	29,691,286	24,567,279	17.26
1989	33,223,785	26,571,879	20.02
1990	35,122,831	30,141,421	14.18
1991	35,694,670	30,176,758	15.46
1992	46,851,682	39,436,636	15.83
1993	45,363,000	39,939,000	11.96
1994	47,553,204	40,612,547	14.60
1995	52,356,145	43,682,506	16.57
1996	54,470,304	46,048,461	15.46
1997	57,242,251	47,331,404	17.31
1998	61,800,247	54,084,772	12.48
1999	60,896,753	52,932,406	13.08
		AVERAGE	**15.35**

In the case of a wastewater treatment facility based on mechanical plant, the total losses would be expected to be around 5 percent. Using data from the Jerash wastewater treatment facility plant, which has a mechanical plant, the average annual losses are around 5.6 percent, as shown in Table IV.5

Table IV.5. Historical Losses at Jerash

YEAR	ANNUAL INFLOW (m^3)	ANNUAL OUTFLOW (m^3)	% LOSSES
1994	506,273	484,989	4.2
1995	494,158	467,311	5.4
1996	556,308	525,348	5.6
1997	567,588	538,774	5.1
1998	659,920	619,405	6.1
1999	585,247	543,150	7.2
		AVERAGE	**5.6**

The above averages were then used to determine the quantity of effluent that can be expected given the influent data from earlier, and the assumption that As Samra converts from waste stabilization ponds to mechanical treatment in 2005. The final estimated values are shown in Table IV.6 and Figure IV.6.

Table IV.6. Estimated effluent discharges from the As Samra WWTP (and Zarqa)

YEAR	EFFLUENT QUANTITY Method I - Modified (m^3)	EFFLUENT QUANTITY Method 2 (m^3)
2000	56,218,667	45,989,526
2005	77,016,765	65,439,493
2010	119,643,646	104,665,690
2015	138,399,065	120,748,353
2020	157,173,958	137,953,726
2025	175,991,379	157,610,683

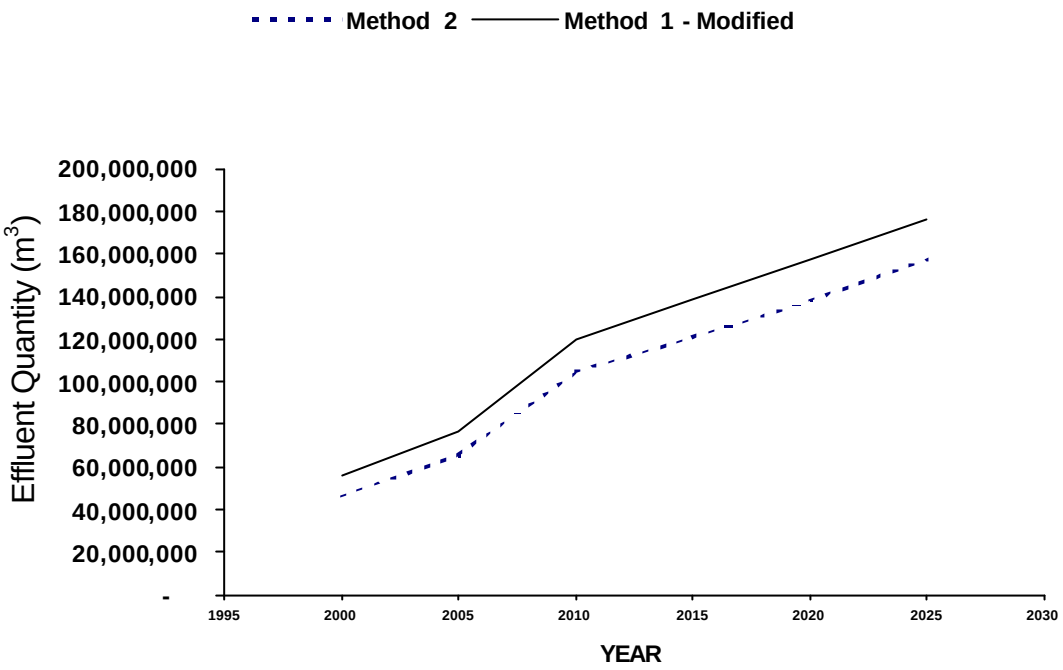


Figure IV.6. Comparison of effluent projections for As Samra (and Zarqa) WWTP.

IV.2. QUALITY OF EFFLUENT

IV.2.1. Existing Situation

Quality data were obtained from the Royal Scientific Society (RSS) and the Water Authority of Jordan (WAJ) for the years 1994 through 1999. The RSS data (RSS (2000) included most parameters listed in the Jordanian Standards, whereas the WAJ (2000) data did not include metal and trace elements, with the exception of Boron.

Using the aforementioned five years of records, the average values for BOD_5, COD, DO, TDS, TSS, PH, NO_3-N, NH_4-N, PO_4-P, CL, SO_4, HCO_3, B and TFCC in both the influent and the effluent were graphed. The graphs also included present limits for the particular parameter in the Jordanian Standard for discharge to wadis. These results are included in Annex A.

On examination of the various data sets, it was found that the WAJ (2000) data did not include metals or trace elements, except for Boron. The RSS (2000) data did include these parameters, but only for 1999. The average and maximum monthly levels along with the level specified in the Jordanian Standards for treated domestic wastewater to be discharged to wadis are presented in Table IV.7.

Table IV.7. Comparison of Jordanian Standards, historical average and maximum, and projected (anticipated) values of water quality parameters in As Samra effluent.

PARAMETER	JORDANIAN STANDARD (893/1995) DISCHARGE TO WADIS MAX LIMIT (1) (mg/l)	AS SAMRA EFFLUENT		
		AVERAGE (mg/l)	MAXIMUM (mg/l)	PROJECTED (mg/l)
BOD_5 (2)	50	80.6	289	30
COD	200	425.6	734	200
DO	>2	4.65	0.87*	4.7
TDS	2000	1218.5	1438	1220
TSS	50	123.9	215	30
PH	6.0-9.0	7.9	8.3	8
Color (PCU)	75	-	-	75
FOG	8	9.04	18	8
Phenol	0.002	0.09	-	0.002
MBAS	25	20.1	35	20
NO_3^- - N	25	6.64	51	7
NH_4^+ - N	15	78.44	104	15
TOTAL - N	30	108.5	278	50
PO_4^- - P	15	15.9	24.1	15
Cl^-	350	355.3	434	350
SO_4^{--}	1000	25.57	54	26
CO_3^{--}	6	-	-	6
HCO_3^-	520	833.7	960	520
Na^+	230	263.3	308	230
Mg^{++}	60	-	-	60
Ca^{++}	400	95	117	95
SAR	9	6.05	18	6
Residual Cl_2 (3)	-	-	-	-
Al	5	0.3	0.9	0.3
As	0.05	0.004	0.005	0.004
Be	0.1	0.01	0.01	0.01
Cu	0.2	0.083	0.27	0.08
F	1	-	-	1
Fe	2	0.19	0.38	0.19
Li	1	0.024	0.025	0.024
Mn	0.2	0.09	0.12	0.09
Ni	0.2	0.02	0.03	0.02
Pb	0.1	0.01	0.02	0.01
Se	0.02	0.009	0.014	0.009
Cd	0.01	0.004	0.005	0.004
Zn	15	0.06	0.08	0.06
CN	0.1	0.03	0.04	0.03
Cr	0.05	0.033	0.043	0.033
Hg	0.001	< 0.0009	0.001	0.0009
V	0.1	< 0.1	< 0.1	0.1
Co	0.05	0.04	0.05	0.04
B	2			

Mo	0.01	< 0.01	< 0.02	0.01
Fecal Coliforms (MPN/100ml)	1000	1.32E+06	7.00E+07	1000
Pathogens –Salmonella (MPN/100 ml)	-	-	-	-
Amoeba & Gardia (Cysts/l)	-	-	-	-
Nematodes (Eggs/l)	<1	0	0	0

Notes:

- Not Recorded/Determined/Specified

(1) Values of Trace Elements and Heavy Metals are calculated based on an average irrigation water quantity of 1000 m3/1000 m2/year.

(2) Filtered - Waste Stabilization Ponds
Not Filtered - Mechanical Treatment Plant

(3) Contact period should not be less than 30 minutes.

MPN Most probable Number

* Minimum value

From Table IV.7. it is evident that the levels of trace elements and heavy metals, including boron, in the effluent from As Samra are generally much lower than those specified by the standards. It should be noted that the Jordanian Standards, except for Zinc and Boron, are either more or as stringent than those in the EPA (EPA, 1992) water reuse guidelines. The Boron level from the EPA is 0.75.

There are, however, a number of other parameters that are not in compliance with the Jordanian Standards. These are: BOD_5; COD; TSS; FOG; NH_4^+ - N; Total Nitrogen; PO_4^- - P; Cl^-; HCO_3^-; and fecal coliforms.

IV.2.2. Projections

The two major events that could significantly impact the quality of the treated effluent from As Samra are the development of new water supplies for Amman and the development of the new facilities at As Samra itself. The development of new water supplies for Amman will alter the quality of the wastewater reaching As Samra. However, with the relatively unknown quality of the new water supply and the specific timing of when this water will be made available, the impact on specific parameters in the wastewater stream is difficult to predict. Harza (1997) hypothesized that new water supplies would result, among other things, in a moderate reduction in the TDS.

The development of the improved facility at As Samra will use the above Jordanian Standards as the specifications for the effluent, with the exception of BOD_5 and TSS, which are both to be 30-mg/l rather than the present 50-mg/l in the standards (Abu Arquob, 2001; Najjar, 2000; and Sundermann, 2000). It is, therefore, assumed that the effluent quality parameters will either comply with or be better than the standards.

Thefinal selection of the treatment process to be used at As Samra lies with the contracted consortium. However, the selected process is likely to reduce the TDS levels in the effluent because the evapo-concentration effect in the present waste stabilization ponds will be reduced. However, a negative aspect of the change in process could be to increase levels of nematode eggs from the present zero level. The activated sludge is less effective at removing nematode eggs and the Jordanian Standards specifies that there be less than

one egg per liter.

Considering the above, it is assumed that the As Samra effluent will be in compliance with the Jordanian Standards for discharge to wadis and that the BOD_5 and TSS will both be 30-mg/l. Where the present level of a parameter is less than the standard required, the present level is maintained as the expected. Expected values of water quality parameters in the As Samra effluent are shown in Table IV.7.

V. OTHER WASTEWATER TREATMENT PLANTS

The other existing wastewater treatment plants are Jerash (east), Abu Nuseir and Baq'a. There is a further wastewater treatment plant planned for Jerash (west). The characterization of the present and expected effluent from these facilities is presented in this sub-section. Jerash east and west are presented together.

V.1. Jerash

The overall plan for wastewater treatment in the greater Jerash area is to, in the short term, continue to connect to the existing wastewater treatment plant at Jerash (east). When the wastewater treatment facility at Jerash (west) is developed, this would serve settlements to the west of Jerash not yet serviced, and would also accept sewage from some of the existing service area for Jerash (east).

V.1.1. Quantity

This sub-section examines the present and projected quantities of effluent from Jerash (east), the expected quantities from Jerash (west) and the projected aggregate from the greater Jerash area.

V.1.1.1. Jerash East

Data on discharge rates from the Jerash (east) wastewater treatment plant were obtained from the Water Authority of Jordan (WAJ, 2000). These data were from January 1994 through December 1999. The annual discharges are graphed in Figure V.1.

Projection of the annual effluent volumes was made by regression of the historical data (method 1), as shown in Figure V.2. below. This was compared with the population-based projection (method 2), which, in the first instance, used the parameters from World Bank (World Bank, 2000) and JICA (JICA, 2000).

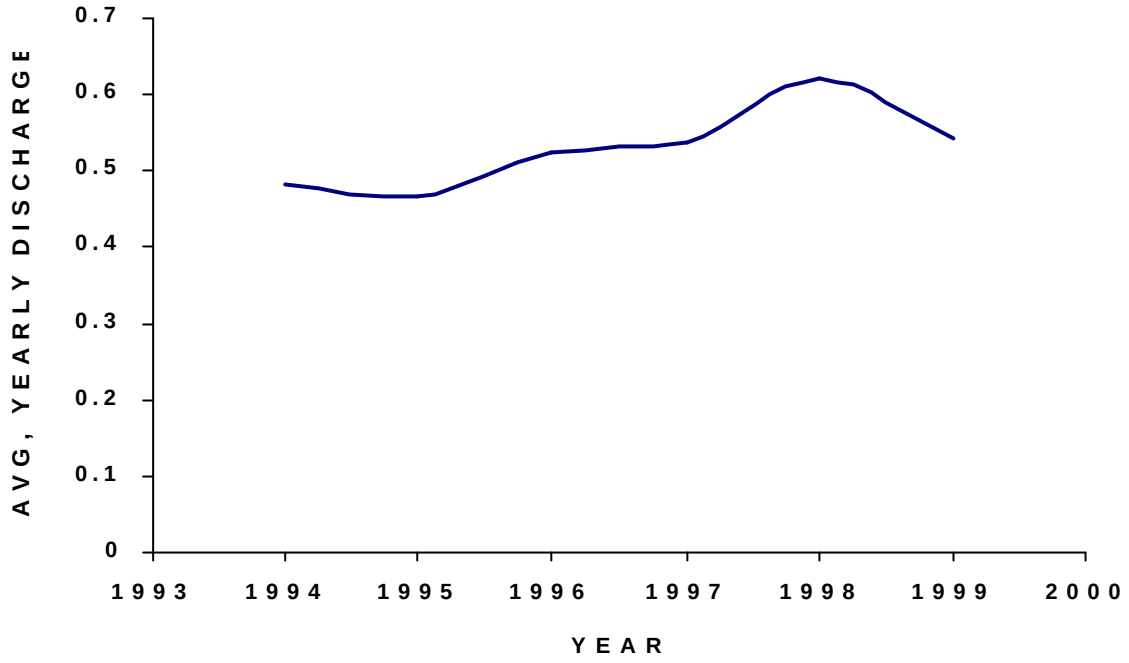


Figure V.1. Jerash (east) actual annual discharges

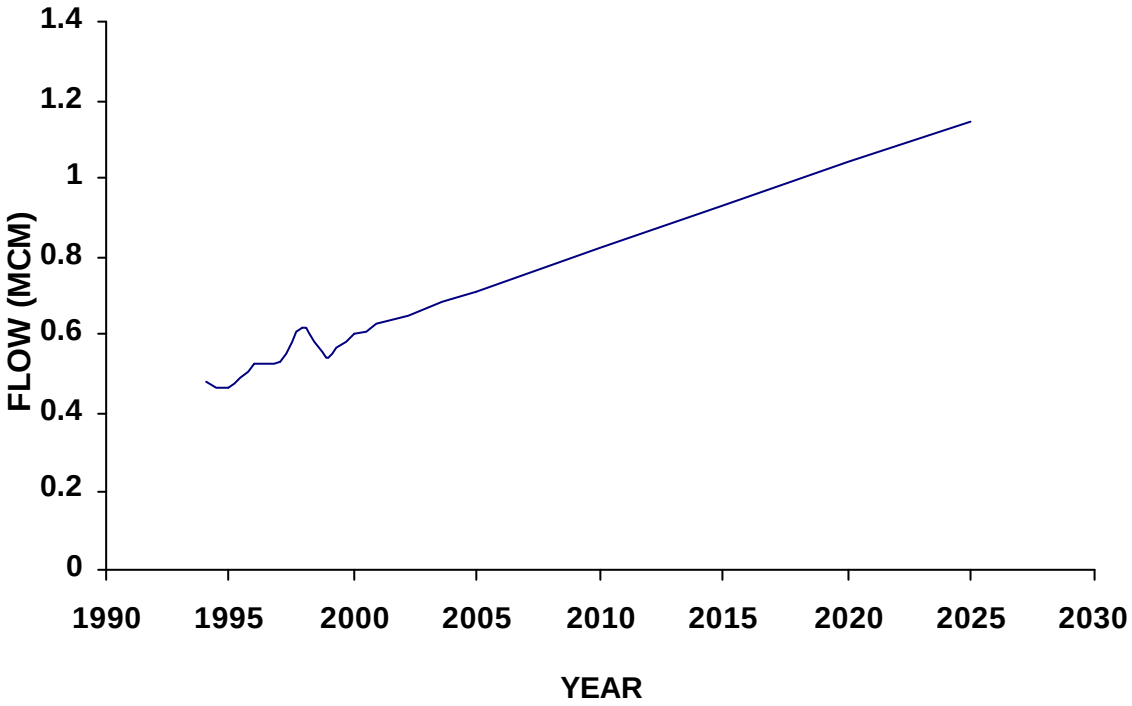


Figure V.2. Projected (Method 1) effluent discharge from Jerash (East)

A preliminary investigation of the population based projections revealed an inconsistency in the definition of service areas. In the initial plan for Jerash (west) the service area included the communities of Jerash camp, Soof, Soof Camp, Sakeb, Reimoon, Ketteh, Dhaher Al Saru, Dair Laiyat, Haddadeh, Moqabelah, Thaghret Asfoor and Amamah, resulting in a total service area population of 58,075, based on the 1994 census figures. However, in the past year Soof, Soof Camp, Dair Laiyat and Asfoor (total population of 22,046 in 1994) have been connected to the Jerash (east) facility, and were being counted as part of the Jerash (east) service area. It is now likely that
these communities will remain connected to Jerash (east) and that the 1994 population in the Jerash (west) service area is 36,029, rather than 58,075.

Figure V.3. compares the projection of the historical records (method 1), and the population-based projections for Jerash (east) with the original service area (method 2a) and with the revised service area (method 2b) as it is today.

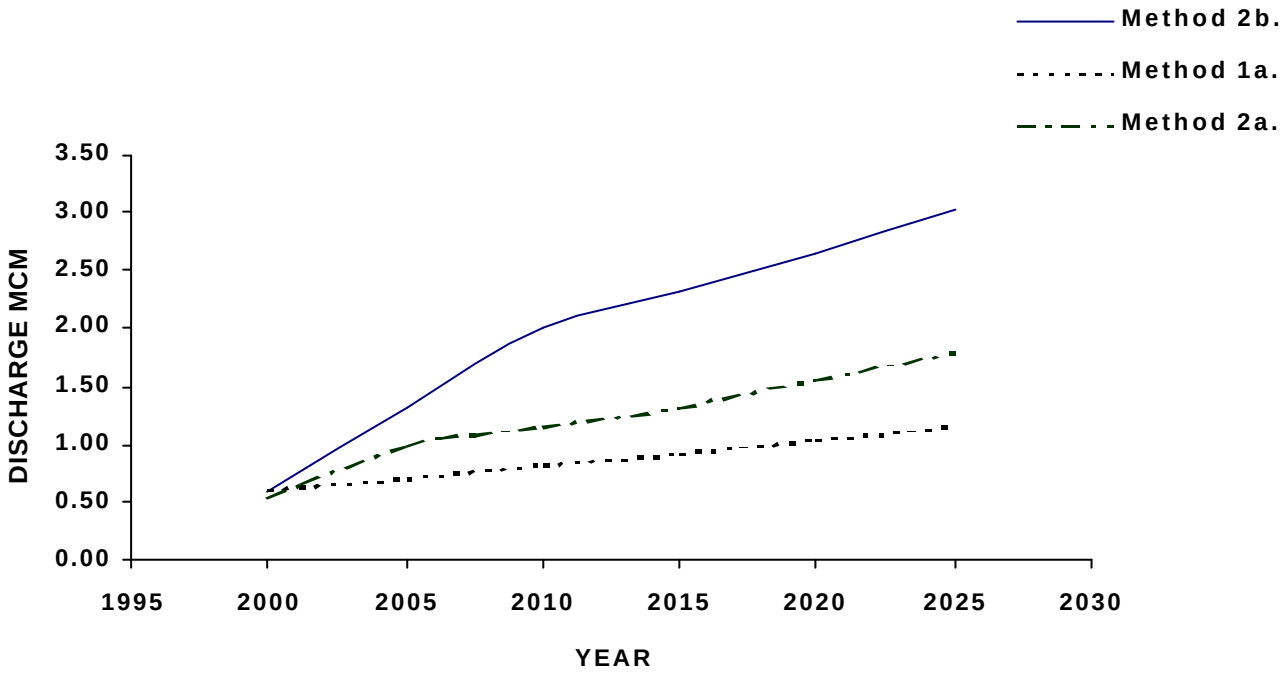


Figure V.3. Comparison of effluent projects for Jerash (East)

The large difference between methods 1 and 2b are due to the recent expansion of the service, as discussed above, and the anticipated 29 percent increase in the per-capita water supply. Modification of the historical-based projection (method 1b) to account for this closely matches the revised population based projections (method 2b), as shown in Figure V.4. and Table V.1.

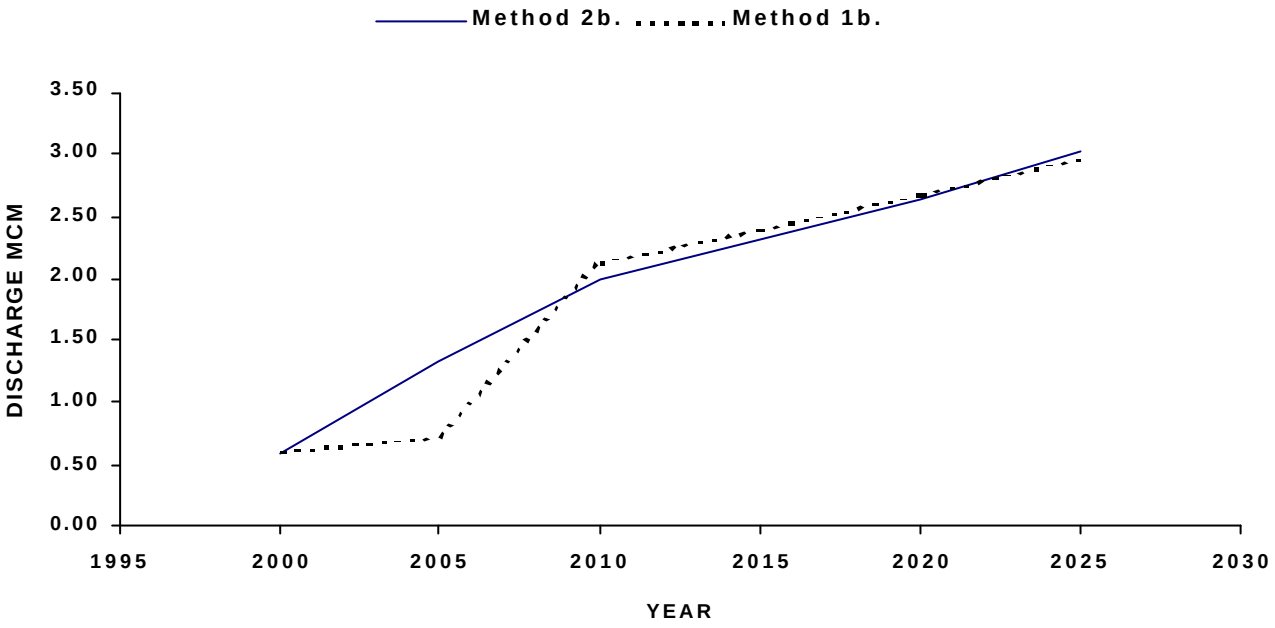


Figure V.4. Comparison of projections from method 1b and method 2b

Table V.1. Comparison of population-based projections for Jerash (east)

METHOD	ESTIMATED EFFLUENT(m^3)					
	2000	**2005**	**2010**	**2015**	**2020**	**2025**
#1b	605,881	714,526	2,123,781	2,404,086	2,684,390	2,964,694
#2b	581,926	1,335,168	2,006,407	2,314,706	2,644,528	3,021,345

The forecast effluent loads that will be used in further study will be those generated from method #2b.

Finally, the plant's design hydraulic capacity of 3500 m^3 will be exceeded once the new service areas are connected. Based on these projections, the plant will need to be expanded sometime before 2010.

V.1.1.2. Jerash West

As mentioned above, there is a planned treatment plant that will serve communities west of Jerash town. It is expected to be operational by the year 2009. As previously discussed, the 1994 population with the Jerash (west) service area is 36,029. Using the parameters developed from Jerash west, the population-based projection of effluent generated from this facility is shown in Table V.2.

Table V.2. Effluent projections for Jerash (west)

PROJECTION	ESTIMATED EFFLUENT (M-m^3)					
	2000	2005	2010	2015	2020	2025
Population-based (36,029 in 1994)	-	-	1.86	2.15	2.40	2.74

V.1.1.3. Aggregate Quantity from Jerash

The total expected effluent discharging from the present and planned wastewater treatment facilities servicing the greater Jerash is shown in Table V.3.

Table V.3. Aggregate effluent projections for Jerash east and west

PROJECTION	ESTIMATED EFFLUENT (M-m^3)					
	2000	2005	2010	2015	2020	2025
Total	0.58	1.34	3.87	4.46	5.04	5.76

V.1.2. Quality

This sub-section examines the present and projected qualities of effluent from Jerash east, and considers the expected qualities from Jerash west.

V.1.2.1. Jerash East

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Jerash (east). The parameters monitored are BOD_5, COD, DO, TDS, TSS, PH, NO_3-N, NH_4-N, PO_4-P, B and TFCC. Unlike As Samra, CL, SO_4, and HCO_3 are not recorded at this site. The data records for NO_3-N, NH_4-N, PO_4-P, B and TFCC are sparse, but they do indicate that none of these parameters are in compliance with the Jordanian Standards. Single readings were observed in September 1999 for Cu, Fe, Mn, Cd and Zn. Fe, Mn and Zn were well within the Jordanian Standards, and Cd was at the standard. However, Cu was not in compliance.

The actual values for BOD_5, COD, DO, TDS, TSS and PH in the influent and effluent from 1994 through 1999, along with the respective level required by the Jordanian Standards (JS 893/1995) for discharge to wadis, are presented in Annex A. These are all in compliance with the Jordanian Standards.

There are no plans for further development of the wastewater treatment facility at Jerash (east); therefore; there should be no major changes in the quality parameters. The present hydraulic load is about half of its design capacity (3500 m^3/day) However, with the recent expansion of the service area and projected population increases, the capacity of the plant

will be exceeded in the near future. If no action is taken then the quality of the effluent will deteriorate.

Considering the above, the present values for the quality parameters of the effluent from Jerash (east) are presented in Table V.4. using average values from the past five years for the parameters monitored. Because no further development of the facility is planned, the projected values of the parameters are taken to be the same as the present values, assuming no overloading occurs.

Table V.4. Actual and projected (anticipated) quality parameters in the Jerash (east) effluent

PARAMETER	JORDANIAN STANDARD (893/1995) DISCHARGE TO WADIS MAX LIMIT (1) (mg/l)	**JERASH (EAST) EFFLUENT** AVERAGE (mg/l)	MAXIMUM (mg/l)	PROJECTED (mg/l)
BOD_5 (2)	50	29.4	77	30
COD	200	118.2	248	120
DO	>2	3.5	7.5	3.5
TDS	2000	1046.7	1593	1050
TSS	50	74.2	216	74
PH	6.0-9.0	7.6	8.12	8
Color (PCU)	75	-	-	-
FOG	8	-	-	-
Phenol	0.002	-	-	-
MBAS	25	-	-	-
NO_3^- - N	25	45.5	288	46
NH_4^+ - N	15	65	210.6	65
TOTAL – N	30	15.5	55	15.5
PO_4^- - P	15	20	42	20
Cl^-	350	444	444	444
SO_4^{--}	1000	-	-	-
CO_3^{--}	6	-	-	-
HCO_3^-	520	-	-	-
Na^+	230	-	-	-
Mg^{++}	60	-	-	-
Ca^{++}	400	-	-	-
SAR	9	-	-	-
Residual Cl_2 (3)	-	-	-	-
Al	5	-	-	-
As	0.05	-	-	-
Be	0.1	-	-	-
Cu	0.2	0.23	0.23	0.23
F	1	-	-	-
Fe	2	0.11	0.11	0.11
Li	1	-	-	-
Mn	0.2	0.07	0.07	0.07
Ni	0.2	-	-	-
Pb	0.1	-	-	-

Se	0.02	-	-	-
Cd	0.01	0.01	0.01	0.01
Zn	15	0.33	0.33	0.33
CN	0.1	-	-	-
Cr	0.05	0.05	0.05	0.05
Hg	0.001	-	-	-
V	0.1	-	-	-
Co	0.05	-	-	-
B	2	-	-	-
Mo	0.01	-	-	-
Fecal Coliforms (MPN/100ml)	1000	>6000	160000	>6000
Pathogens –Salmonella (MPN/100 ml)	-	-	-	-
Amoeba & Gardia (Cysts/l)	-	-	-	-
Nematodes (Eggs/l)	<1	0*	0*	0

V.1.2.2. Jerash West

This proposed wastewater treatment plant is expected to be operational by the year 2009. In the absence of any data, it is assumed that the quality of the effluent will be the same as those for Jerash east except where the parameters does not comply with the present Jordanian standards for discharge to wadis. In such cases the parameter was set to the Jordanian standard. It is assumed that, as with the new As Samra facility, BOD_5 and TSS will be 30-mg/l rather than the persent 50-mg/l in the standards.

Table V.5. Projected (anticipated) quality parameters for Jerash east and west

PARAMETER	JORDANIAN STANDARD (893/1995) DISCHARGE TO WADIS MAX LIMIT (1) (mg/l)	**PROJECTED** EAST (mg/l)	WEST (mg/l)
BOD_5 (2)	50	30	30
COD	200	120	120
DO	>2	3.5	3.5
TDS	2000	1050	1050
TSS	50	74	30
PH	6.0-9.0	8	8
Color (PCU)	75	-	-
FOG	8	-	-
Phenol	0.002	-	-
MBAS	25	-	-
NO_3^- - N	25	46	25
NH_4^+ - N	15	65	15
TOTAL – N	30	15.5	15.5
PO_4^- - P	15	20	15
Cl^-	350	444	350
SO_4^{--}	1000	-	-
CO_3^{--}	6	-	-
HCO_3^-	520	-	-

Na^{+}	230	-	-
Mg^{++}	60	-	-
Ca^{++}	400	-	-
SAR	9	-	-
Residual Cl_2 (3)	-	-	-
Al	5	-	-
As	0.05	-	-
Be	0.1	-	-
Cu	0.2	0.23	0.2
F	1	-	-
Fe	2	0.11	0.11
Li	1	-	-
Mn	0.2	0.07	0.07
Ni	0.2	-	-
Pb	0.1	-	-
Se	0.02	-	-
Cd	0.01	0.01	0.01
Zn	15	0.33	0.33
CN	0.1	-	-
Cr	0.05	0.05	0.05
Hg	0.001	-	-
V	0.1	-	-
Co	0.05	-	-
B	2	-	-
Mo	0.01	-	-
Fecal Coliforms (MPN/100ml)	1000	>6000	1000
Pathogens –Salmonella (MPN/100 ml)	-	-	-
Amoeba & Gardia (Cysts/l)	-	-	-
Nematodes (Eggs/l)	<1	0	0

V.2. Abu Nuseir

V.2.1. Quantity

Data on effluent discharge rates for the Abu Nuseir wastewater treatment plant were obtained from the Water Authority of Jordan (WAJ, 2000). These data were from January 1994 through December 1999. The annual discharges are graphed in Figure V.5.

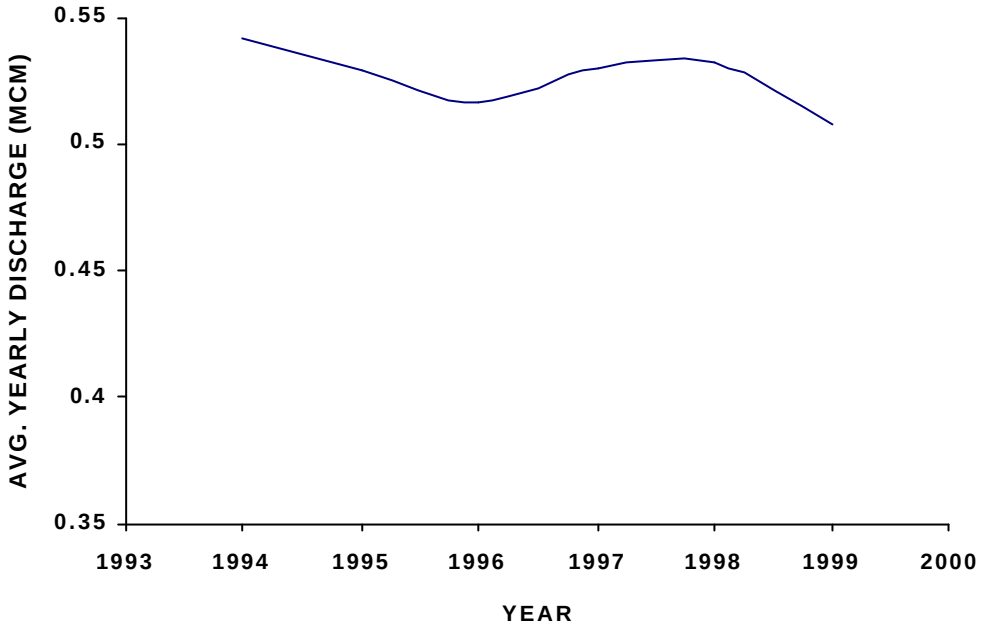


Figure V.5. Abu Nuseir actual annual effluent discharges

By means of regression, projections of expected annual discharges through the planning horizon (year 2025), were made, the results of which are shown in Figure V.6.

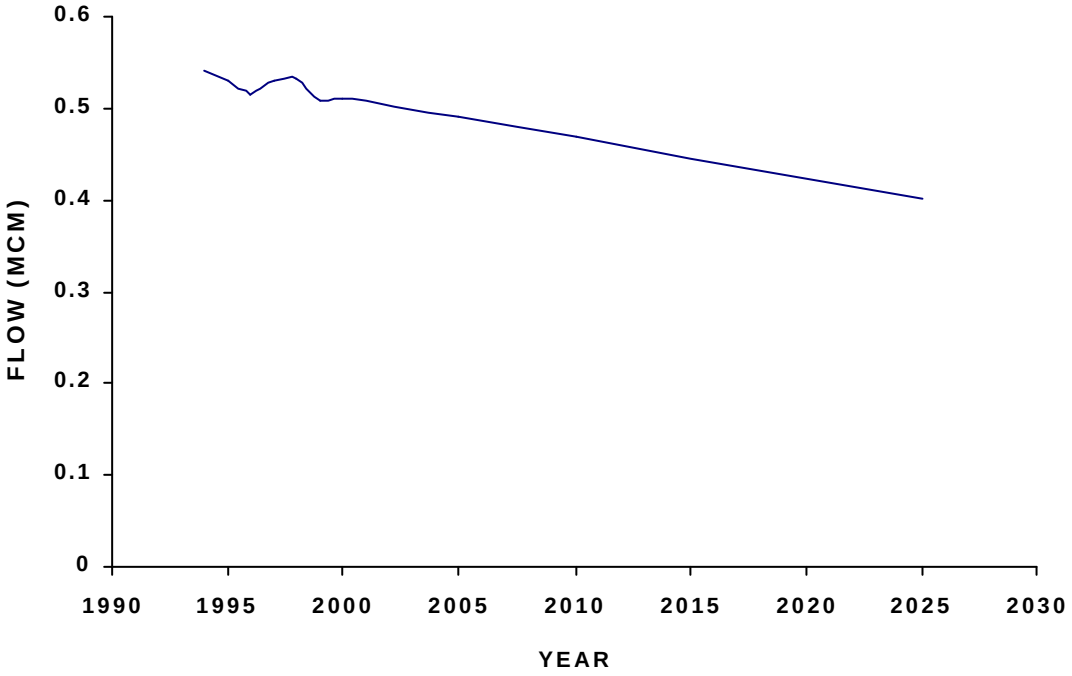


Figure V.6. Projected effluent discharges for Abu Nuseir

The downward trend of historical effluent discharges is most likely due to the reduction in per-capita water supply for the past few years in the Greater Amman area. Although the same phenomenon has occurred within the service areas of the other wastewater treatment plant, in those cases the rates of population increase has resulted in a general upward trend in the total effluent discharged. This has not been the case at Abu Nuseir, and suggests a lower rate of population increase. From follow-up visits to the Abu Nuseir service area, significant expansion of the service area is unlikely.

From the above, the projected effluent discharge at the end of the planning period (2025) is estimated to be 400,000- m^3. In reality, this should be higher because of the expected increase in per capita water supplies and some increase in population. From JICA (2000), the population-based projection estimates the effluent quantity to be 1,432,123-m^3 by the end of the planning period. Considering the physical constraints on the service area, this is high.

Assuming a similar increase in per capita water supply as the other service areas, but a population growth of two percent rather than the 3.5 percent generally used, the resultant modified projection based on historical data is compared with the population-based projection in Table V.6.

Table V.6. Comparison of population-based and modified historical effluent data projections for Abu Nuseir

PROJECTION	ESTIMATED EFFLUENT(m^3)					
	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Population-based	500,621	571,712	973,684	1,123,298	1,253,510	1,432,123
Modified historical effluent	511,469	489,782	603,843	666,692	736,082	812,694

The treatment plant design capacity is 4000 m^3/day or 1,460,000 m^3/annum, which will handle the projected quantity of influent through the end of the planning period.

V.2.2. Quality

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Abu Nuseir. The parameters monitored are BOD_5, COD, DO, TDS, TSS and PH. For each of these parameters, the measured values in the influent and the effluent at Abu Nuseir, along with the relevant Jordanian Standard, were graphed for 1994 through 1999 and are presented in Annex C.

Of the parameters monitored, all comply with the Jordanian Standards for discharge to wadis. As no developments are planned at Abu Nuseir, it assumed that all these

parameters would remain constant in the future. Table V.7. presents the actual (average and maximum) and projected values for the quality parameters for Abu Nuseir.

Table V.7. Projected (anticipated) quality parameters in the Abu Nuseir effluent

PARAMETER	JORDANIAN STANDARD (893/1995) DISCHARGE TO WADIS MAX LIMIT (1) (mg/l)	ABU NUSEIR AVERAGE (mg/l)	ABU NUSEIR MAXIMUM (mg/l)	ABU NUSEIR PROJECTED (mg/l)
BOD_5 (2)	50	22.5	63	23
COD	200	84.4	135	85
DO	>2	-	-	-
TDS	2000	839.3	1460	840
TSS	50	37.5	470	38
PH	6.0-9.0	7.5	8.3	8
Color (PCU)	75	-	-	-
FOG	8	-	-	-
Phenol	0.002	-	-	-
MBAS	25	-	-	-
NO_3^- - N	25	-	-	-
NH_4^+ - N	15	-	-	-
TOTAL – N	30	-	-	-
PO_4^- - P	15	-	-	-
Cl^-	350	-	-	-
SO_4^{--}	1000	-	-	-
CO_3^{--}	6	-	-	-
HCO_3^-	520	-	-	-
Na^+	230	-	-	-
Mg^{++}	60	-	-	-
Ca^{++}	400	-	-	-
SAR	9	-	-	-
Residual Cl_2 (3)	-	-	-	-
Al	5	-	-	-
As	0.05	-	-	-
Be	0.1	-	-	-
Cu	0.2	-	-	-
F	1	-	-	-
Fe	2	-	-	-
Li	1	-	-	-
Mn	0.2	-	-	-
Ni	0.2	-	-	-
Pb	0.1	-	-	-
Se	0.02	-	-	-
Cd	0.01	-	-	-
Zn	15	-	-	-
CN	0.1	-	-	-
Cr	0.05	-	-	-
Hg	0.001	-	-	-
V	0.1	-	-	-
Co	0.05	-	-	-

B	2	-	-	-
Mo	0.01	-	-	-
Fecal Coliforms (MPN/100ml)	1000	-	-	-
Pathogens –Salmonella (MPN/100 ml)	-	-	-	-
Amoeba & Gardia (Cysts/l)	-	-	-	-
Nematodes (Eggs/l)	<1	-	-	-

V.3. Baq'a

V.3.1. Quantity

Data on discharge rates for the Baq'a wastewater treatment plant were obtained from the Water Authority of Jordan (WAJ, 2000). These data were from January 1994 through December 1999. The annual discharges are graphed in Figure V.7.

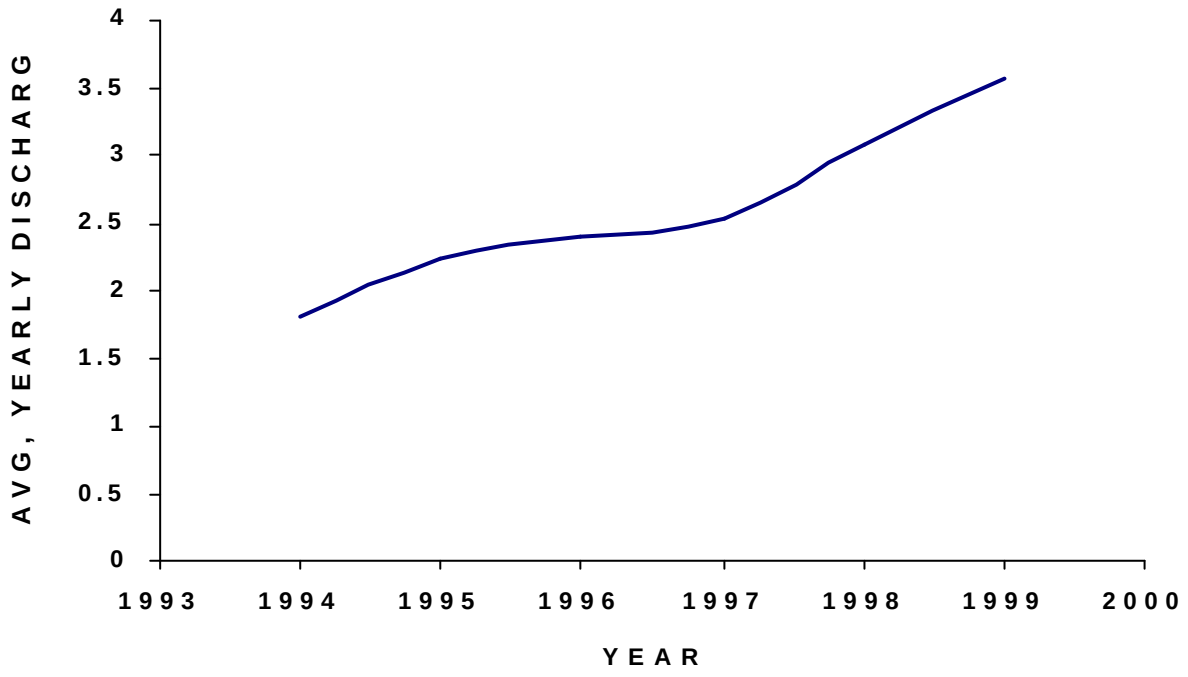


Figure V.7. Baq'a annual effluent discharges

By means of regression, projections of expected annual discharges through the planning horizon (year 2025), were made, the results of which are shown in Figure V.8. This projection suggests that estimated annual effluent discharge of 3.75 M-m^3 in the year 2000 will increase to around 12 M-m^3 by the year 2025.

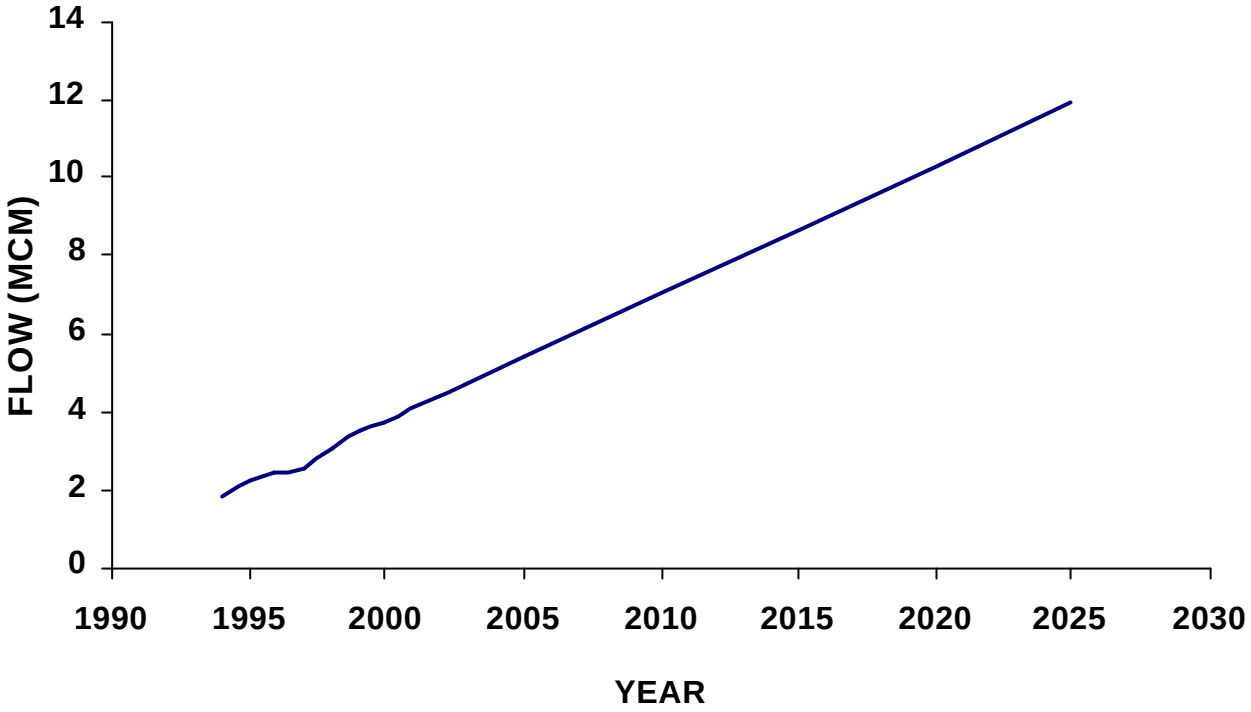


Figure V.8. Projected effluent discharges from Baq'a

Table V.8 and Figure V.9. compares this effluent discharge record-based projection with the population based projection, and demonstrates good agreement in this case.

Table V.8. Comparison of population-based and historical effluent data projections for Baq'a

PROJECTION	ESTIMATED EFFLUENT (M-m^3)					
	2000	2005	2010	2015	2020	2025
Population-based (Method 2)	3.8	5.3	8.4	9.7	10.9	12.4
Historical effluent (Method 1)	3.8	5.4	7.0	8.7	10.3	11.9

The deviation of the two projections at year 2005 is primarily due to the 29 percent increase in per-capita water supply. Figure V.10 compares the above two projections with the projection of the historical effluent data that has been modified to account for the increased water supply. This results in higher effluent discharges after year 2010, up to 15.4 M-m^3 by the year 2025. The divergence of the modified projection and the population projection in this case is due to the present high level of connectivity (95 percent) within the Baq'a service zone, whereas with the other wastewater treatment plants there is a predicted increase in connectivity.

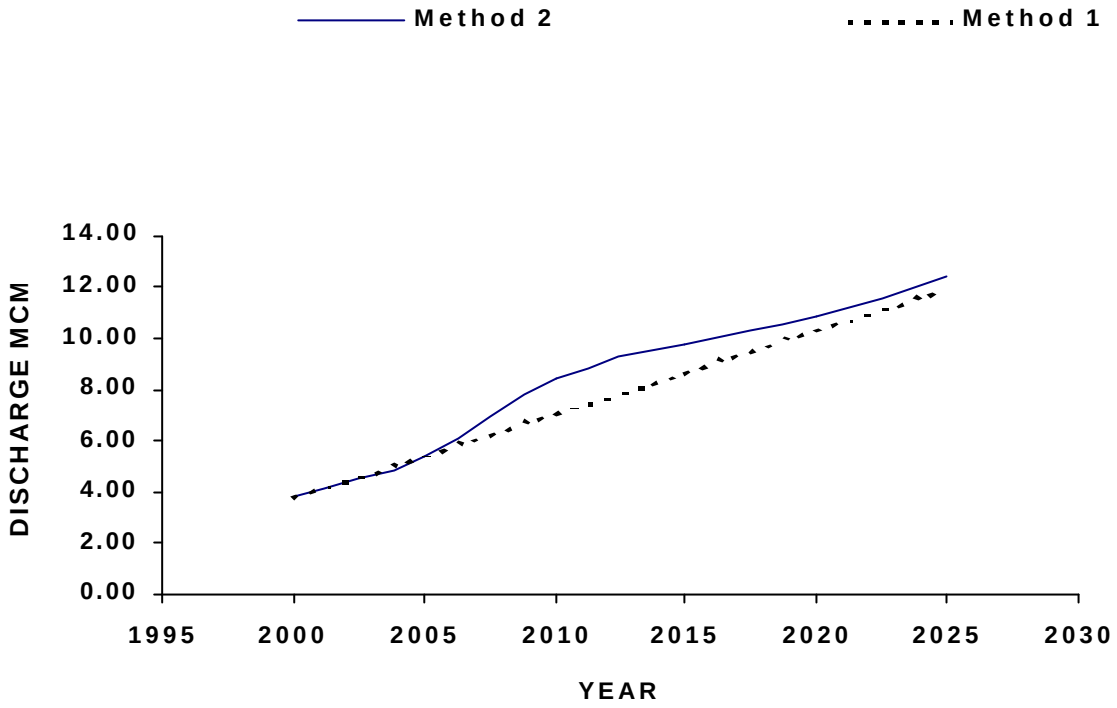


Figure V.9. Comparison of population-based and historical effluent data projections for Baq'a

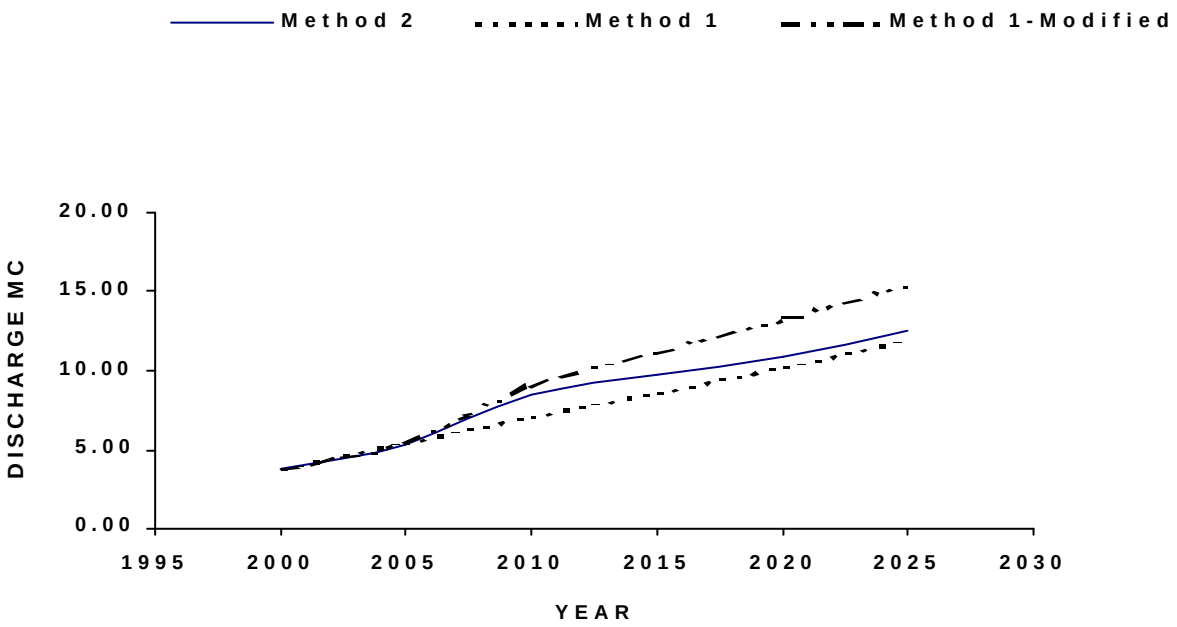


Figure V.10. Population-based, historical effluent data, and modified historical effluent data projections for Baq'a.

For Baq'a, the population based projections as presented Table V.8 are used as the forecast for the quantity of effluent expected through the planning horizon of year 2025.

V.3.2. Quality

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Baq'a. The parameters monitored are BOD_5, COD, TDS, and TSS. For each of these parameters, the measured values in the influent and the effluent at Baq'a, along with the relevant Jordanian Standard, were graphed for 1994 through 1999 and are presented in Annex D.

Despite the Baq'a facility being relatively effective at lowering the values of the monitored parameters in the influent, only the TDS (Total Dissolved Solids) in the effluent complies with the Jordanian Standards for discharge to wadis. BOD_5, COD and TSS are consistently not in compliance with the Jordanian Standard for discharge to wadis. The present facility is overloaded. The new plant will be completed in the last quarter of this year (2000).

Considering the above, the present values for the quality parameters characteristics of the effluent from Baq'a are presented in Table V.9. using average values from the past five years for the parameters monitored, and the actual values from As Samra for the parameters not monitored at Baq'a. Table V.9. also presents expected values for each of the parameters. These were determined by assuming that for the parameters that presently are not in compliance with the Jordanian Standards they would be when the new facilities become available. As with As Samra, the total nitrogen is projected to fall to 30-mg/litre. Many of the parameters that are not monitored at Baq'a (primarily trace elements and heavy metals) are well within the Jordanian Standards at As Samra, but it would be prudent to determine the typical level of these parameters in the Baq'a influent.

Table V.9. Projected (anticipated) quality parameters in the Baq'a effluent

PARAMETER	JORDANIAN STANDARD (893/1995) DISCHARGE TO WADIS MAX LIMIT (1) (mg/l)	BAQ'A AVERAGE (mg/l)	BAQ'A MAXIMUM (mg/l)	BAQ'A PROJECTED (mg/l)
BOD_5 (2)	50	235.2	608	50
COD	200	513.5	1151	200
DO	>2	-	-	>2
TDS	2000	1200.7	1766	1200
TSS	50	152.8	356	50
PH	6.0-9.0	-	-	-
Color (PCU)	75	-	-	-
FOG	8	-	-	-
Phenol	0.002	-	-	-
MBAS	25	-	-	-
NO_3^- - N	25	-	-	-
NH_4^+ - N	15	87.9	129	15
TOTAL – N	30	-	-	30
PO_4^- - P	15	-	-	-
Cl^-	350	-	-	-
SO_4^{--}	1000	166	166	166

CO_3^{--}	6	-	-	-
HCO_3^-	520	-	-	-
Na^+	230	-	-	-
Mg^{++}	60	-	-	-
Ca^{++}	400	-	-	-
SAR	9	-	-	-
Residual Cl_2 (3)	-	-	-	-
Al	5	-	-	-
As	0.05	-	-	-
Be	0.1	-	-	-
Cu	0.2	-	-	-
F	1	-	-	-
Fe	2	-	-	-
Li	1	-	-	-
Mn	0.2	-	-	-
Ni	0.2	-	-	-
Pb	0.1	-	-	-
Se	0.02	-	-	-
Cd	0.01	-	-	-
Zn	15	-	-	-
CN	0.1	-	-	-
Cr	0.05	-	-	-
Hg	0.001	-	-	-
V	0.1	-	-	-
Co	0.05	-	-	-
B	2	-	-	-
Mo	0.01	-	-	-
Fecal Coliforms (MPN/100ml)	1000	53867.3	160000	1000
Pathogens –Salmonella (MPN/100 ml)	-	-	-	-
Amoeba & Gardia (Cysts/l)	-	-	-	-
Nematodes (Eggs/l)	<1	0*	0*	0

VI. CONCLUSIONS

VI.1. Quantity of Effluent

With the exception of Abu Nuseir, the revised population-based projections for the effluent discharges from the wastewater treatment plants are considered reasonable. In the case of Abu Nuseir, the projection is high and, therefore, that developed from the historical projections is used. The contribution of Abu Nuseir to the total volume of effluent discharged into the basin is negligible.

The cumulative projections for all effluent discharged into the wadi Zarqa system are shown in Figure VI.1 and in Table VI.1.

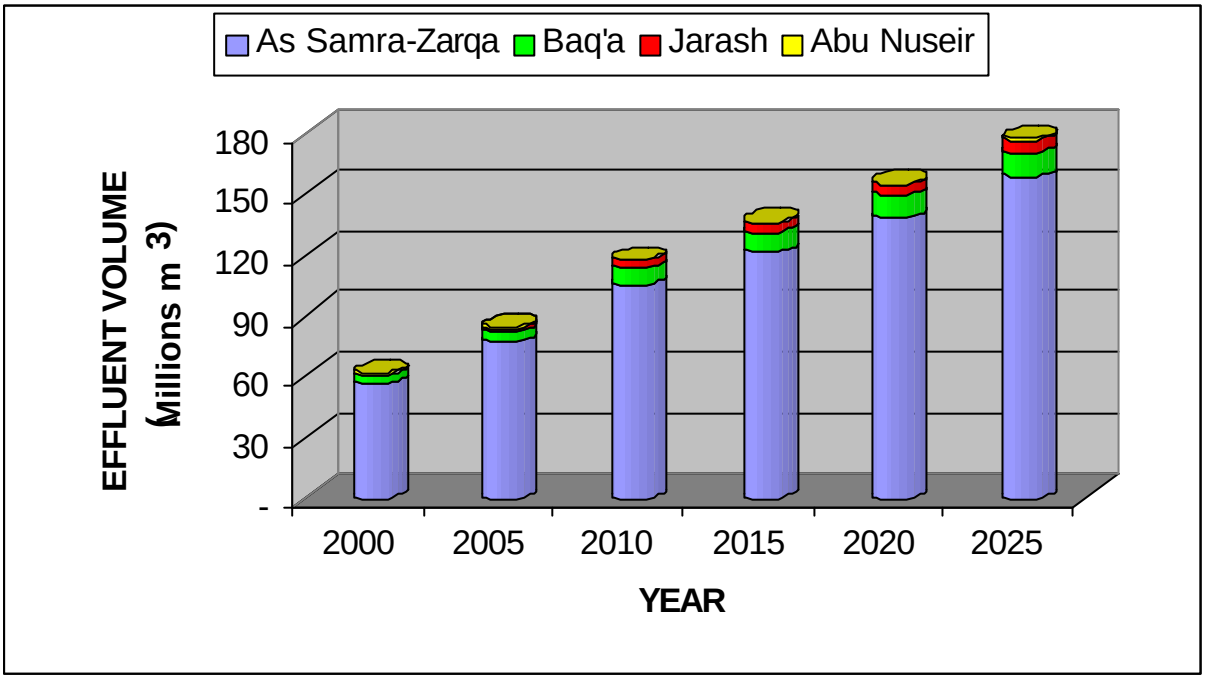


Figure VI.1. Projection of total effluent discharge (MCM annual flow) to the Zarqa Wadi

Table VI.1. Projection of total effluent discharge (MCM annual flow) to the Zarqa Wadi

TREATMENT PLANT	2000	2005	2010	2015	2020	2025
As Samra-Zarqa	56.2	77.0	104.7	120.7	137.9	157.6
Jerash	0.6	1.3	3.9	4.5	5.0	5.8
Abu Nuseir	0.5	0.5	0.6	0.7	0.7	0.8
Baq'a	3.8	5.3	8.4	9.7	10.9	12.4
TOTAL	**61.1**	**84.1**	**117.6**	**135.6**	**154.6**	**176.6**

The increased rate of effluent production between years 2005 and 2010 is due to the expected increase in per capita water supply.

The total effluent discharged from As Samra and the planned Zarqa facilities is projected to remain the major source of effluent although falling from approximately 93 percent at present to 90 percent by the year 2025.

The As Samra-Zarqa facilities are by far the major sources of effluent in the basin. Also, the analysis of these facilities demonstrated that a ten percent variation in the quantity was quite likely. From this, it would be prudent to consider a variation in the effluent volumes in the basin of at least ten percent.

VI.2. Quality of Effluent

Considering that the effluent volume from As Samra and the planned Zarqa facilities will be by far the dominant quantity in the Amman-Zarqa basin, the quality, at least at a basin level, will be dictated by the quality from these facilities. Also, the monitoring programs at the three minor facilities (Jerash, Abu Nuseir and Baq'a) are much less rigorous than the As Samra program. Some parameters, such as copper (Cu) at Jerash, do not comply with the Jordanian Standards, but, because of the relative volumes involved, their impact on the quality of the water in King Talal Reservoir, will be minimal.

Despite the relatively low impact of the quality parameters from the minor treatment facilities at the basin level, the reuse of this water close to the facilities requires that the level of these parameters be monitored and accounted for in the development and management of such options.

VI.3. Shortfall in Water Supplies

As was discussed in Chapter II, the projections for effluent generated are based on per capita water suppy rising by 29 percent in the next five to ten years, and meeting the needs of an expanding population. This requires relatively aggressive development of new water sources, as is scheduled by the Ministry of Water and Irrigation. In the event that one or more of these new developments is delayed, it is possible that the water supply targets will not be met. In such a case, the actual wastewater effuent volumes in the future are more likely to match the linear projections based on the historical effluent volumes ("method 1"), as developed in Chapter II. This is about 15 percent less than the anticipated volume.

VI.4. Other Aspects

The present situation with respect to monitoring of effluent discharges from As Samra wastewater treatment plant is relatively good, with both WAJ (Water Authority of Jordan) and the RSS (Royal Scientific Society) monitoring major parameters, trace elements and heavy metals. The annual report provided by RSS is a particularly useful review of the situation. It is not clear just how this information is utilized and whether problems are identified and addressed in a timely manner. Also, the fact that the RSS contract is with WAJ, who are also operating the facility, could constrain the final utility of the monitoring.

At the other three plants only WAJ is directly monitoring the effluent discharges. Only the major parameters are sampled and not necessarily consistently. As shown above, the volumes are relatively low with respect to the entire Amman-Zarqa basin. However, if this water is to be safely recycled the characteristics of the effluent needs to be better defined.

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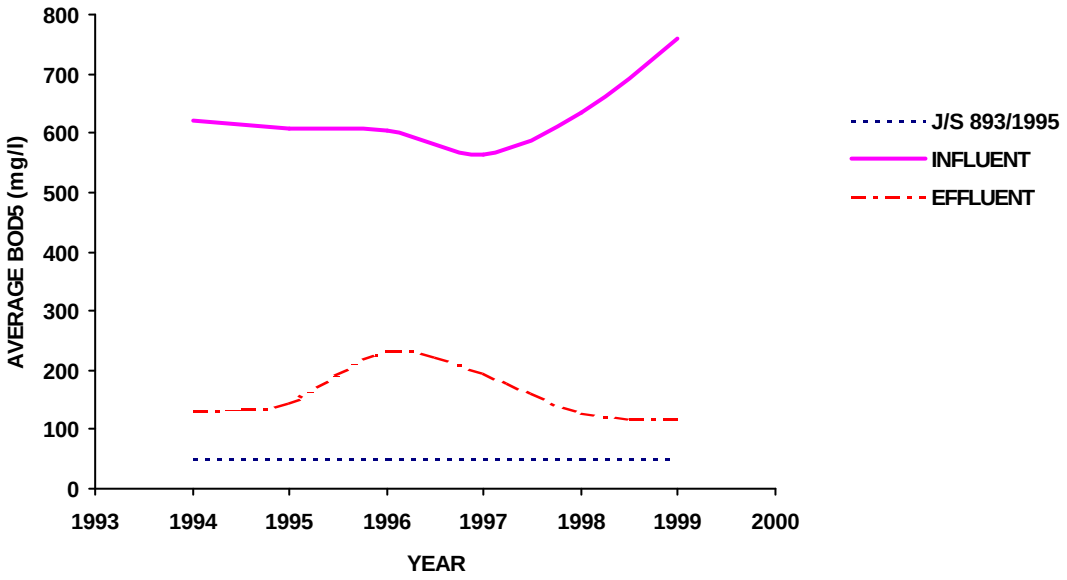
ANNEX A

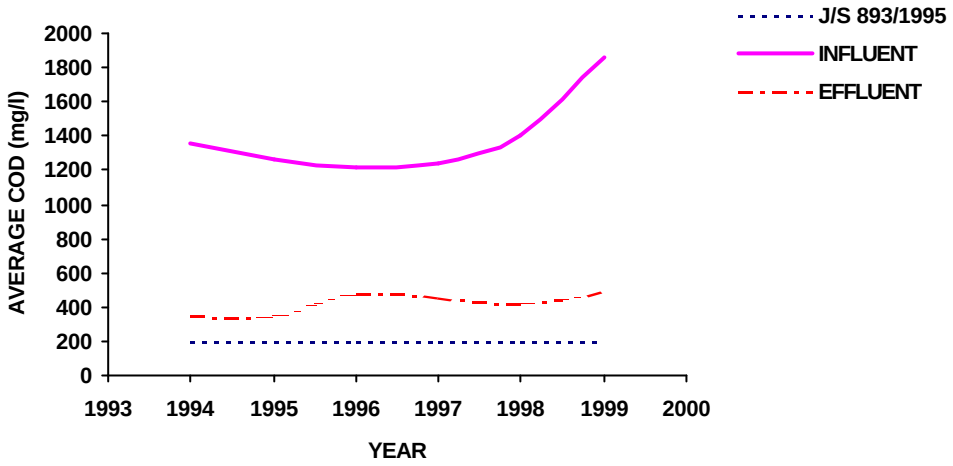
COMPARISON OF INFLUENT & EFFLUENT QUALITY AT AS SAMRA

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at As Samra. The parameters monitored are BOD_5, COD, DO, TDS, TSS, PH, NO_3-N, NH_4-N, PO_4-P, CL, SO_4, HCO_3, B and TFCC. The actual value for each parameter in the influent and effluent from 1994 through 1999, along with the respective level required by the Jordanian Standards (JS 893/1995) for discharge to wadis, are presented below.



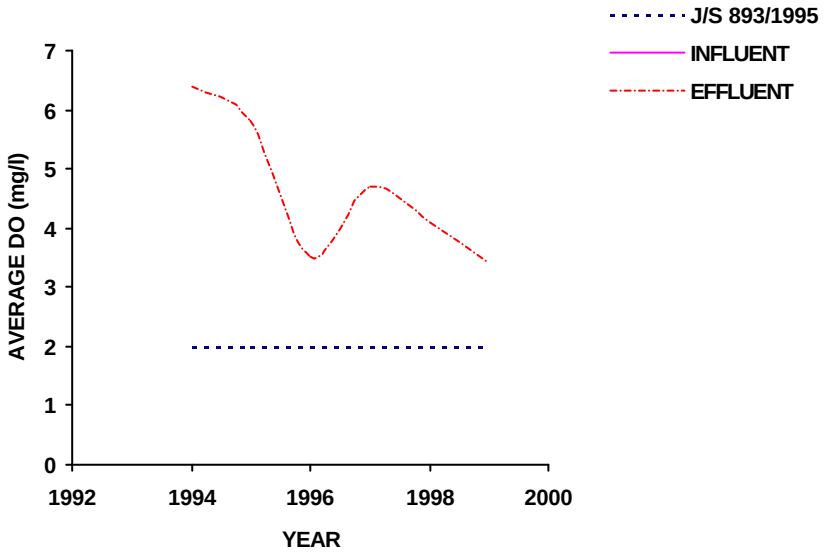
AS SAMRA BOD5

Despite the As Samra facility reducing the BOD_5 levels by around 80 percent of the influent levels, the BOD_5 levels of the effluent are still above 50 mg/l allowed by the Jordanian Standards for discharge to wadis. However, the new facilities to be developed at As Samra are to be designed to reduce the BOD_5 level to 30 mg/l.



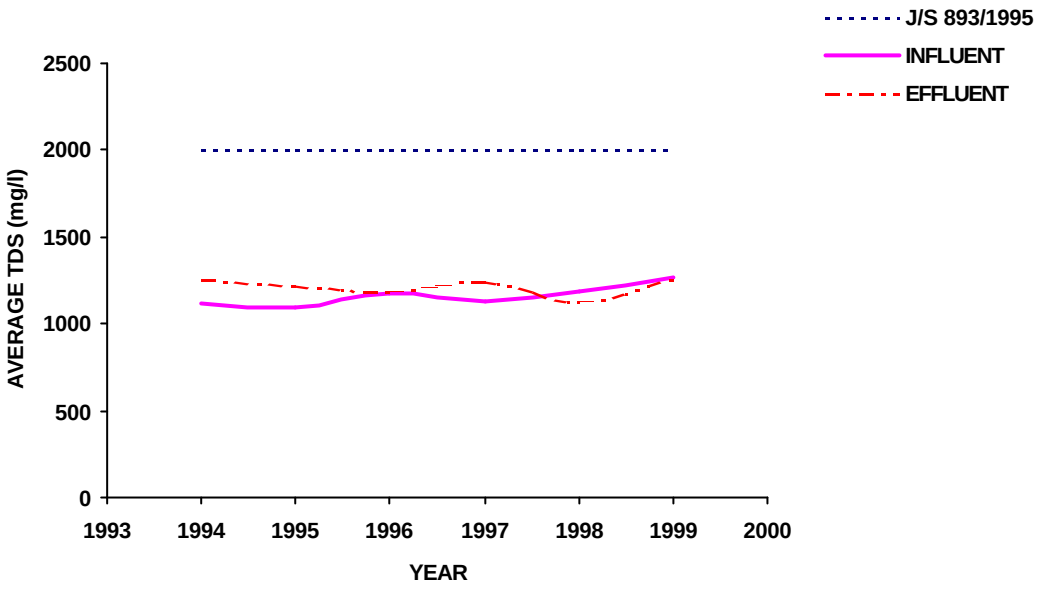
AS SAMRA COD

The situation with respect to COD is similar to that of BOD_5, with the present levels almost double that specified by the relevant Jordanian Standard.



AS SAMRA DO

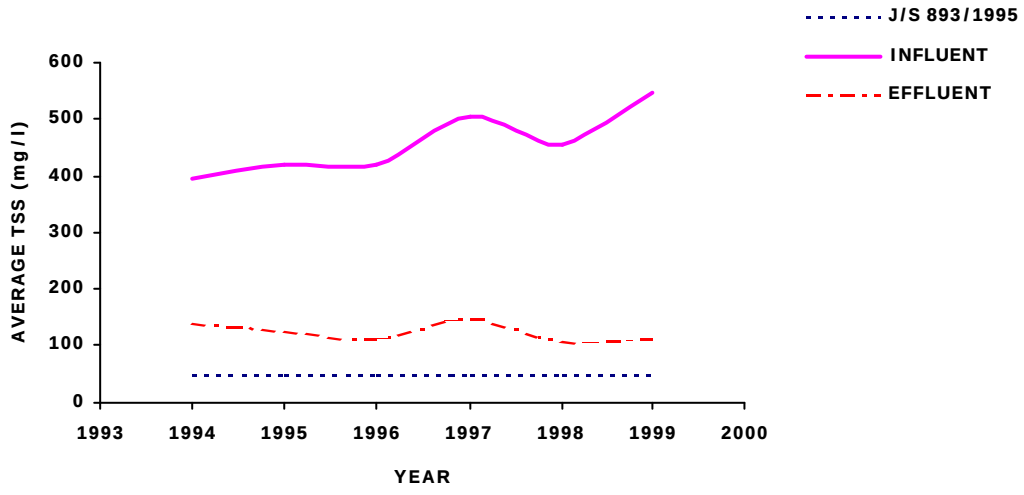
The Jordanian Standards specifies that the dissolved oxygen in the effluent be greater than 2 mg/l. For this parameter, As Samra is in compliance.



AS SAMRA TDS

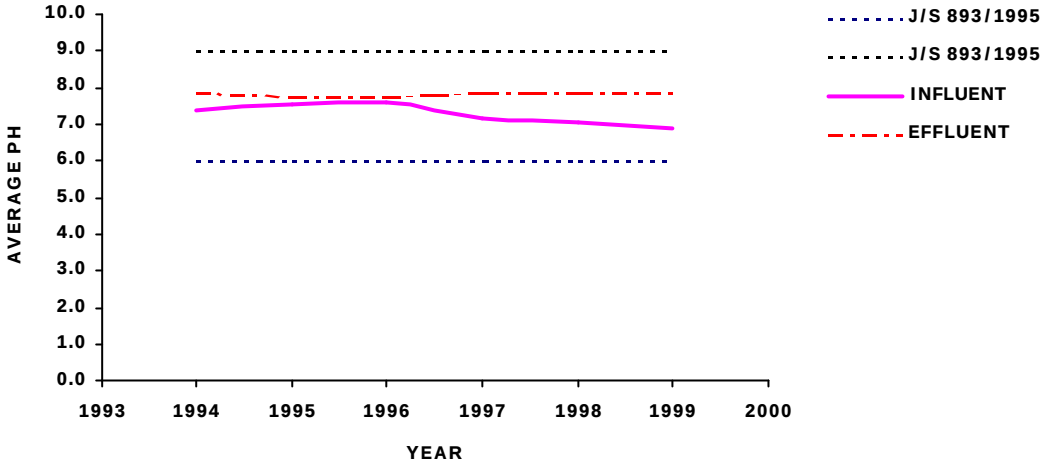
According to the available data, there is little appreciable change in the level of total dissolved solids between the influent and the effluent. This would suggest a discrepancy in the data as the evaporation from the ponds should result in relatively higher TDS levels in the effluent.

The effluent levels are well within the limits specified in the Jordanian Standards.



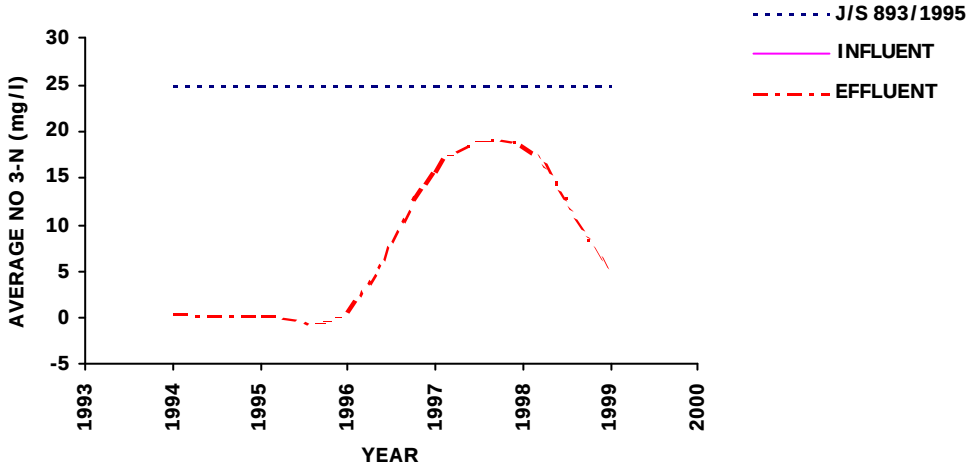
AS SAMRA TSS

Despite the As Samra facility being relatively effective at removing suspended solids, the TSS level in the effluent is more than double the Jordanian Standard of 50 mg/l.



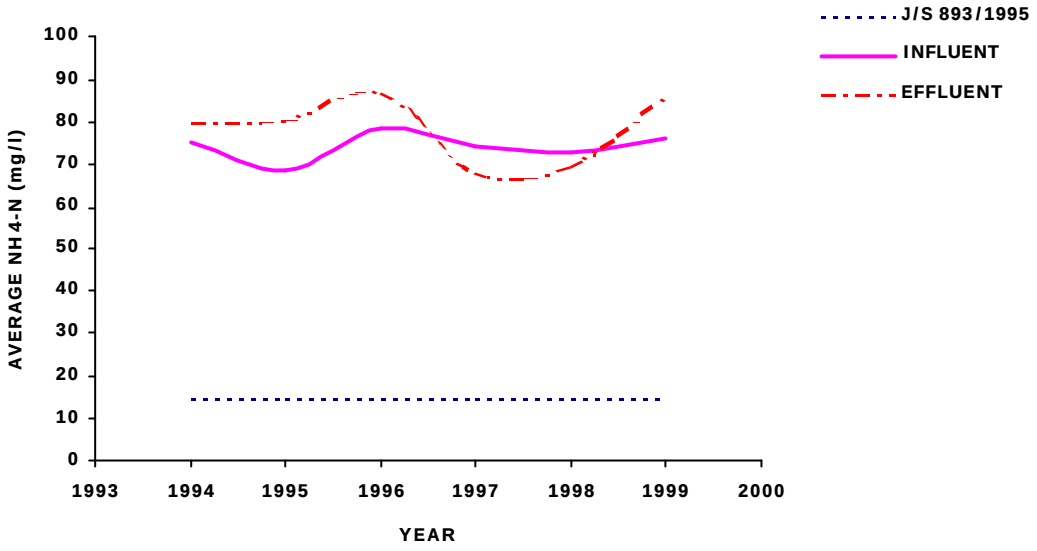
AS SAMRA PH

The PH of the effluent is relatively constant at around 8.0, which is within the range (6.0 – 9.0) specified by the Jordanian Standards.



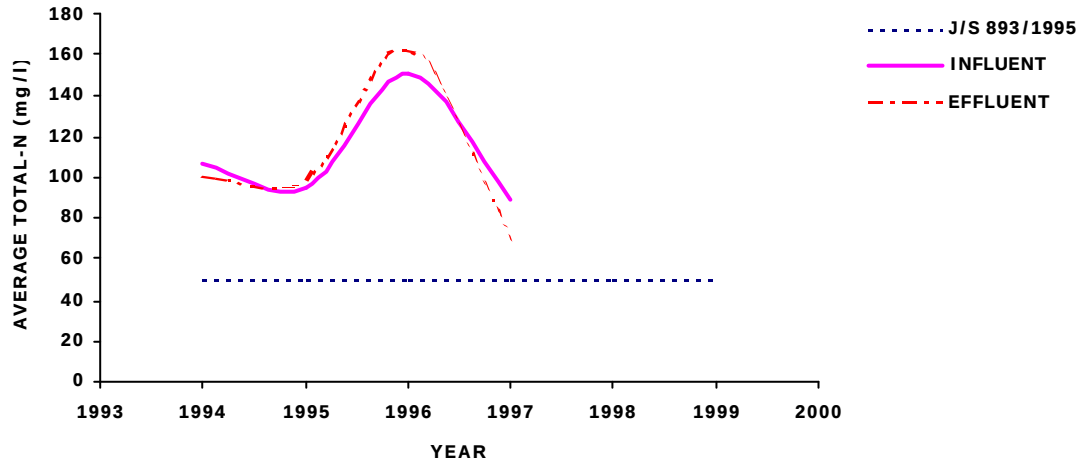
AS SAMRA NO3-N

The Jordanian Standard for nitrate nitrogen (NO_3-N) in the effluent is to not exceed 25 mg/l, which As Samra does not.



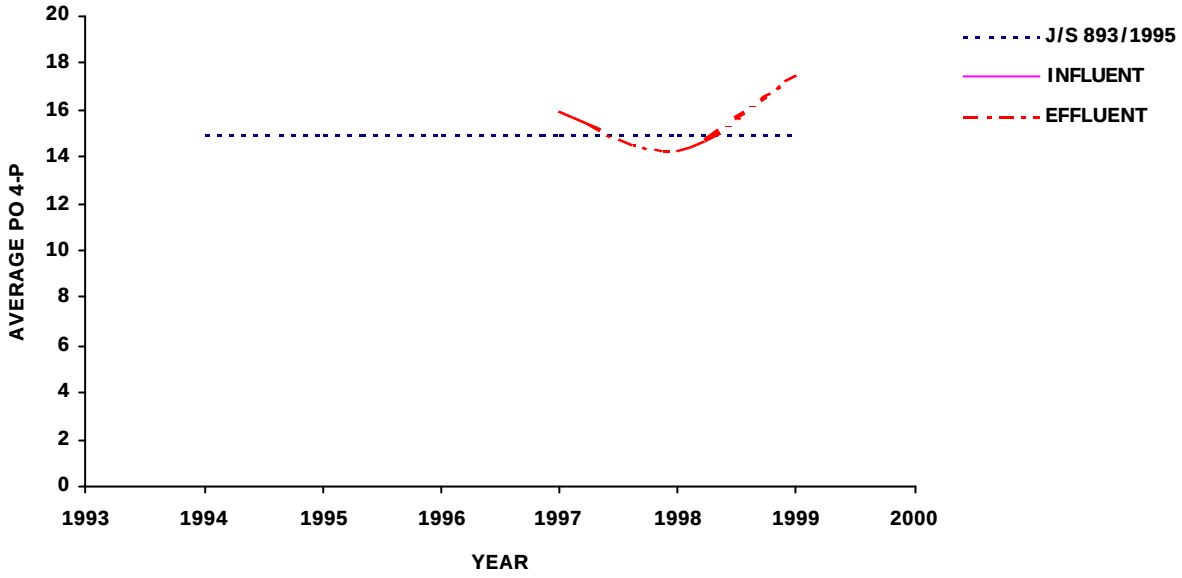
AS SAMRA NH4-N

The Jordanian Standard for ammonia nitrogen (NH_4-N) in effluent to be discharged to wadis is a maximum of 15 mg/l. The present levels in effluent from As Samra are more than five times greater than the standard.



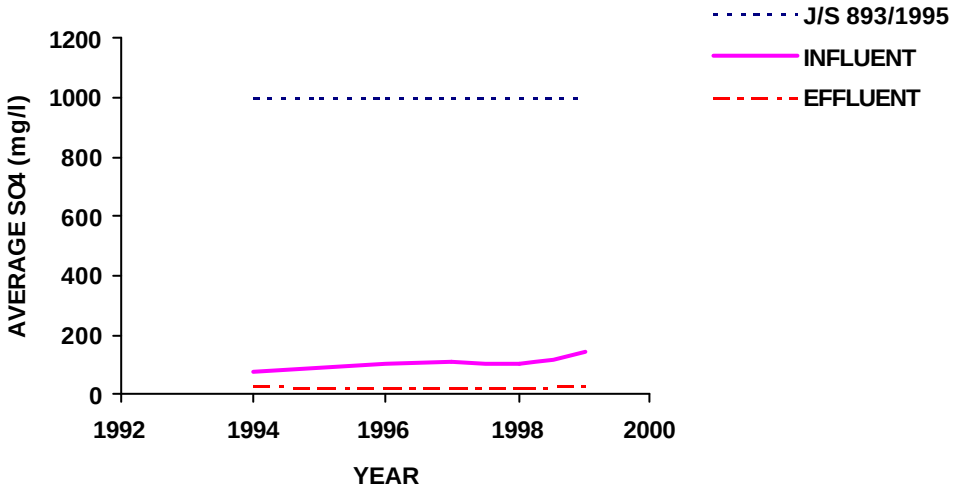
AS SAMRA TOTAL -N

The WAJ (2000) records for As Samra do not include total nitrogen after 1997. The present Jordanian Standards have a maximum of 50 mg/l. The present As Samra facility does not alter the total nitrogen levels of the influent. The effluent, therefore, has total nitrogen levels well above the Jordanian Standards.



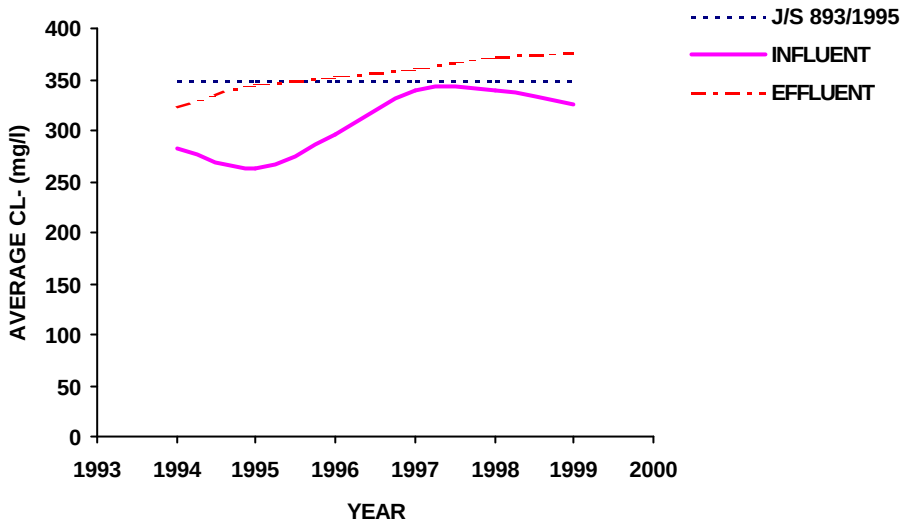
AS SAMRA PO4-P

Data on phosphate (PO_4-P) levels are only available from 1997 to 1999. However, these data show that the phosphate levels in the As Samra effluent are generally at or above the Jordanian Standard of 15-mg/l.



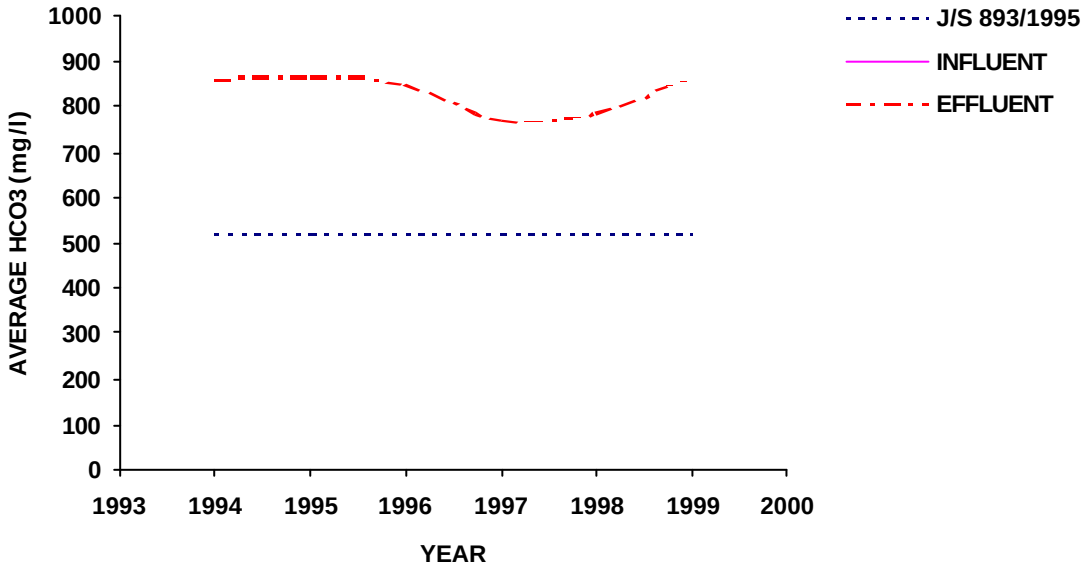
AS SAMRA SO4

The maximum limit for sulfates (SO_4) in effluent discharged to wadis is, according to the Jordanian Standards, 1000-mg/l. As can be seen in the above figure, sulfates are well below this standard.



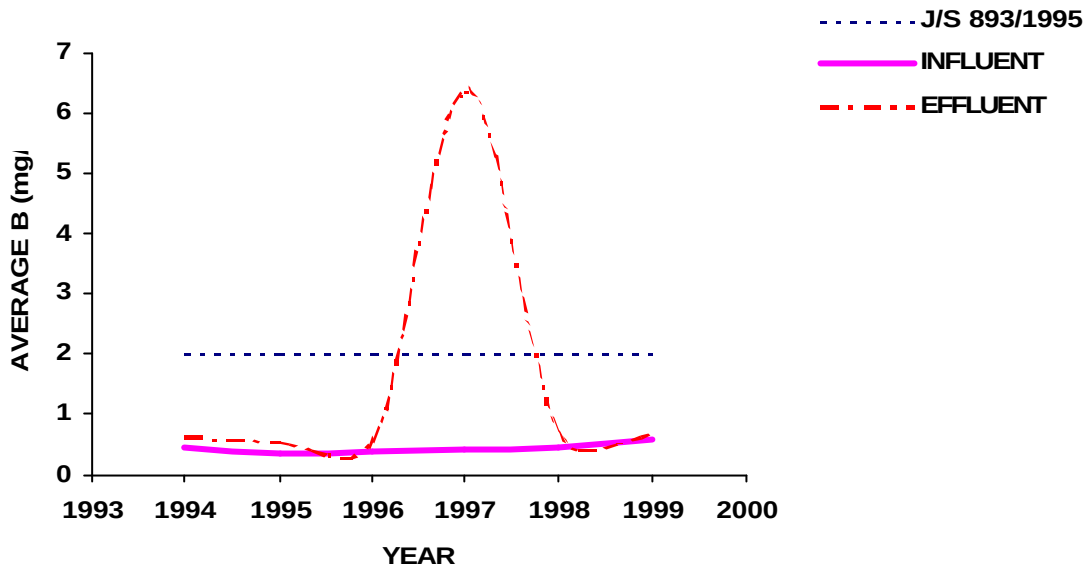
AS SAMRA CL-

Chlorides (CL^-) in effluent, according to the Jordanian Standards, should be less than 350-mg/l. The present levels at As Samra are at or slightly above this limit.



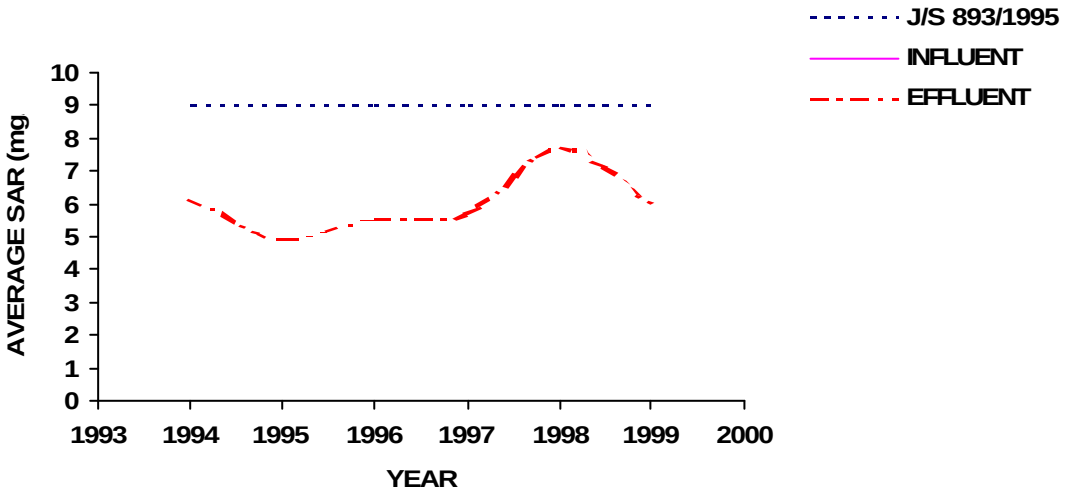
AS SAMRA HCO3

The Jordanian Standard for bicarbonates (HCO_3) in effluent is a maximum of 520-mg/l. As shown above, the present effluent from As Samra exceeds this limit.



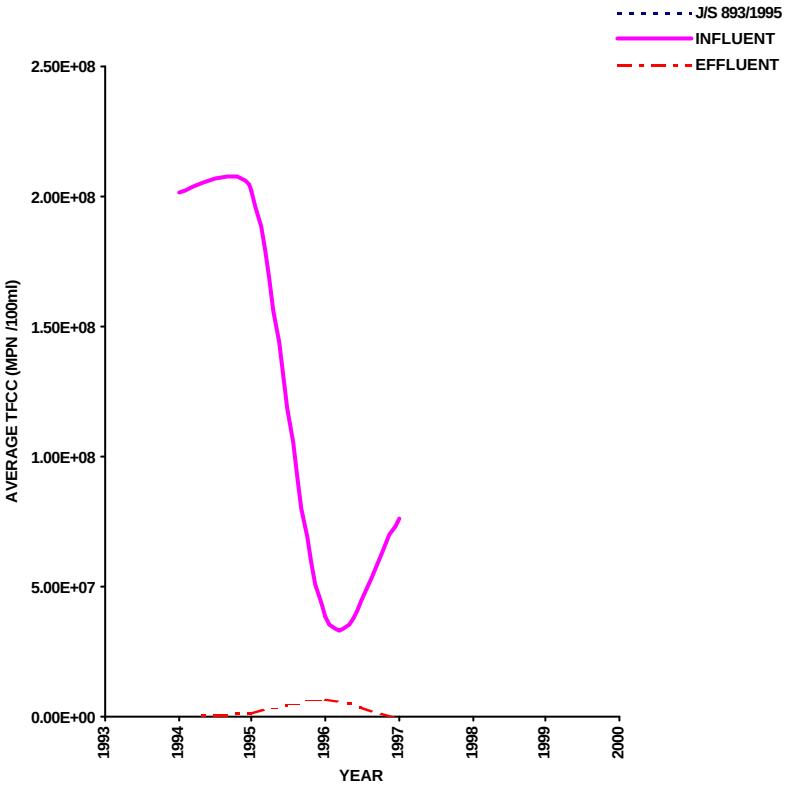
AS SAMRA B

The Jordanian Standards for boron (B) in effluent discharges to wadis is 2-mg/l. Although there has been a history of possible boron issues, in the As Samra effluent (Harza, 1997), this has been addressed, and the levels are not generally low, as shown above. The apparent highly elevated level in 1997 is entirely due to a spike in for the month of February. It is suspected that this is an anomaly.



AS SAMRA SAR

The Sodium Absorption Ratio (SAR) in effluent discharges to wadis should not exceed 9-mg/l, according to the Jordanian Standards. The chart shows that As Samra is in compliance.



AS SAMRA TFCC

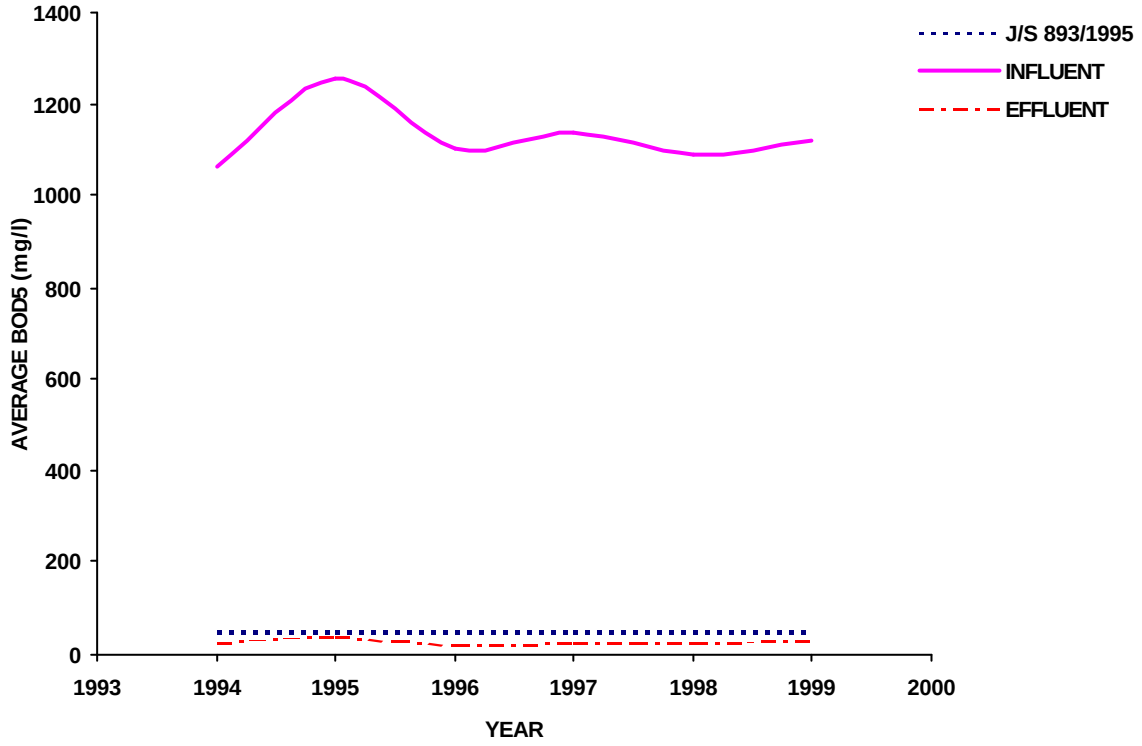
The total fecal coliform count (TFCC) from As Samra is dramatically higher than the 1000 MPN/100ml specified in the Jordanian Standards.

ANNEX B

COMPARISON OF INFLUENT & EFFLUENT QUALITY AT JERASH (EAST)

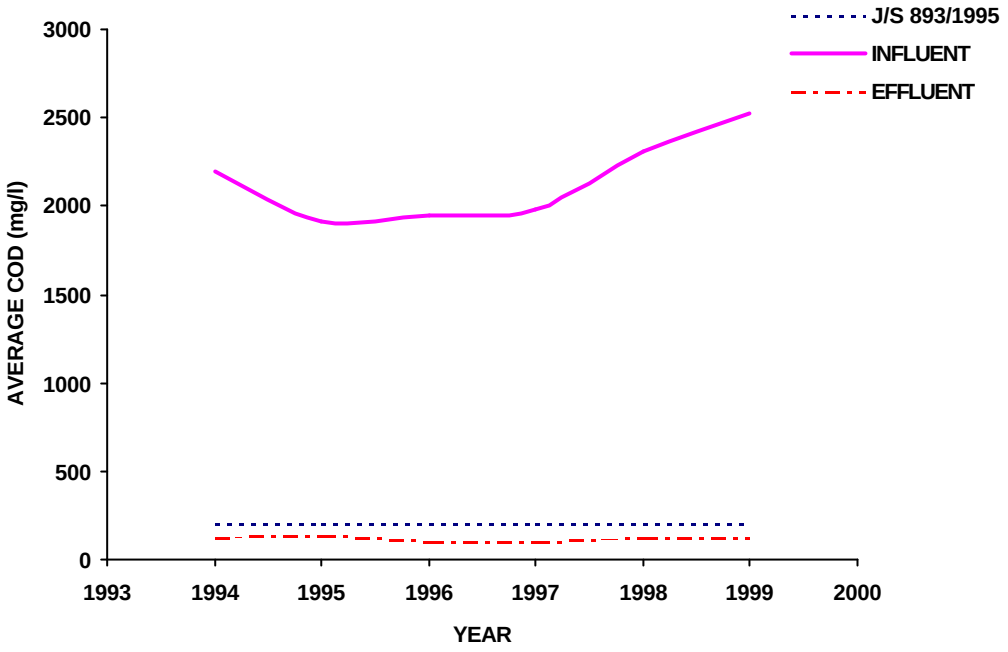
The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Jerash (east). The parameters monitored are BOD_5, COD, DO, TDS, TSS, PH, NO_3-N, NH_4-N, PO_4-P, B and TFCC. Unlike As Samra, CL, SO_4, and HCO_3 are not recorded at this site. The data records for NO_3-N, NH_4-N, PO_4-P, B and TFCC are sparse, but they do indicate that for each parameters that the levels are well above the Jordanian Standards.

The actual values for BOD_5, COD, DO, TDS, TSS and PH in the influent and effluent from 1994 through 1999, along with the respective level required by the Jordanian Standards (JS 893/1995) for discharge to wadis, are presented below.



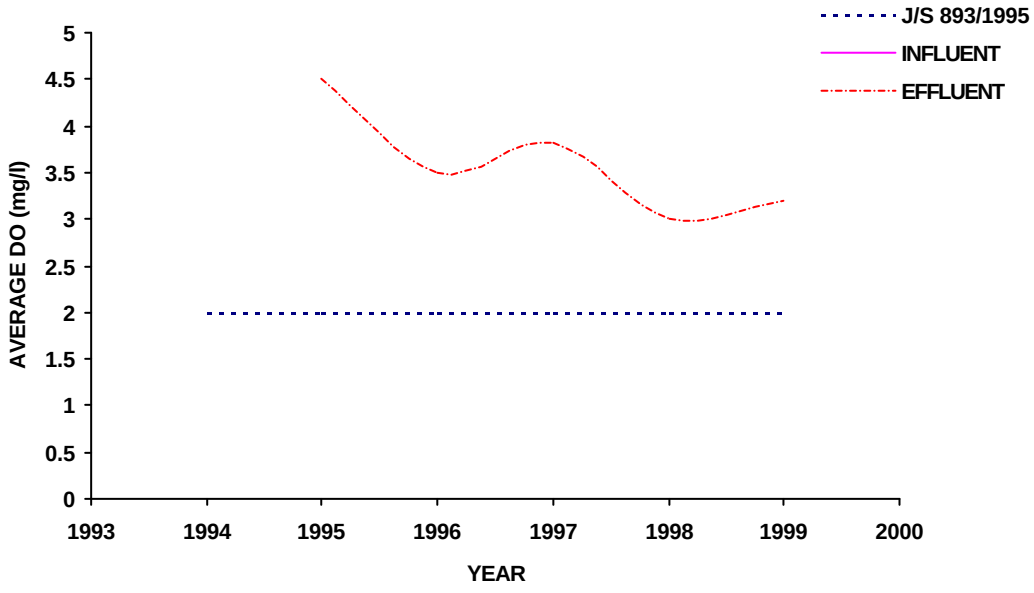
JARASH BOD5

The Jerash (east) facility is very effective at reducing the BOD_5 from around 1100-mg/l to below the 50-mg/l allowed by the Jordanian Standards for effluent discharge to wadis.



JARASH COD

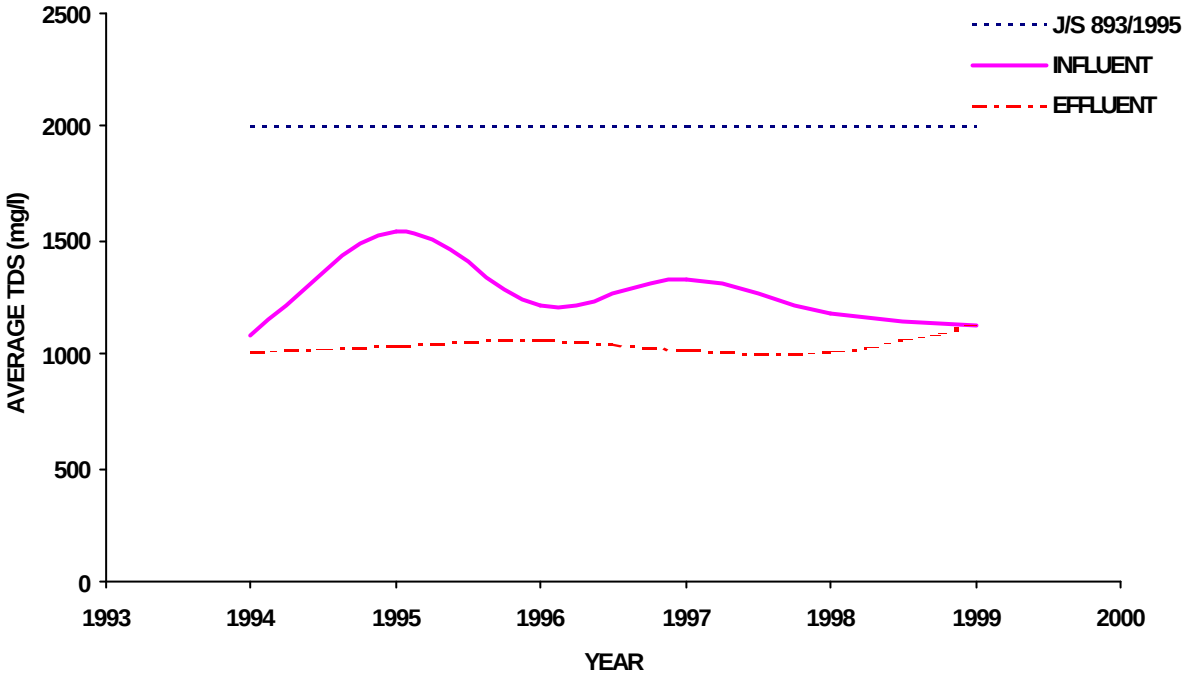
The situation with respect to COD is similar to that of BOD_5, with the present levels below that required by the Jordanian Standard.



JARASH DO

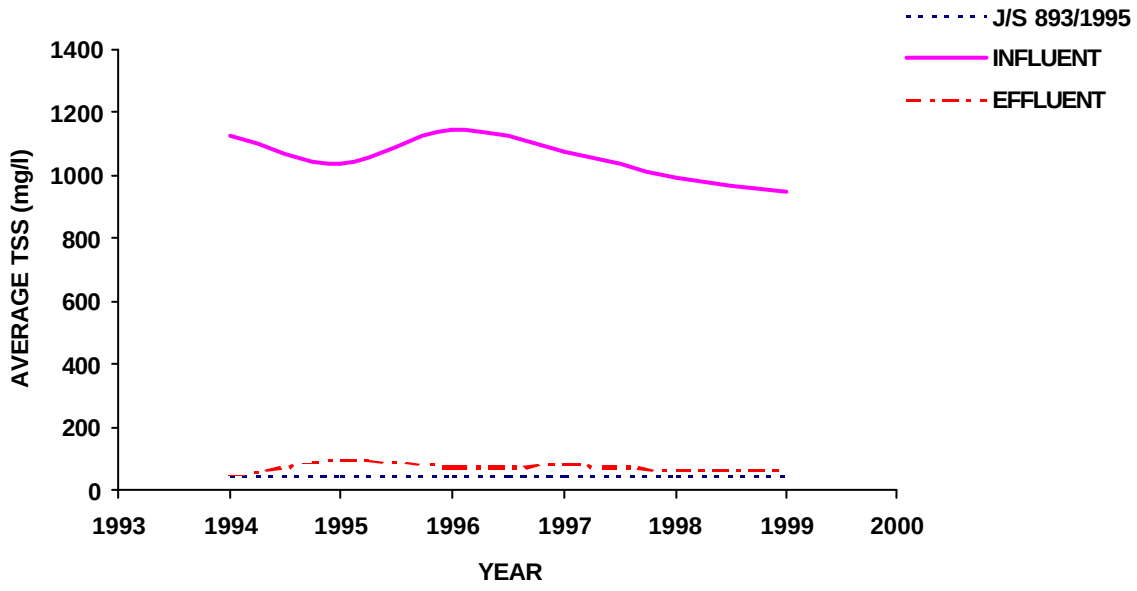
The Jordanian Standards specifies that the dissolved oxygen in the effluent be

greater than 2 mg/l. For this parameter, Jerash (east) is in compliance.



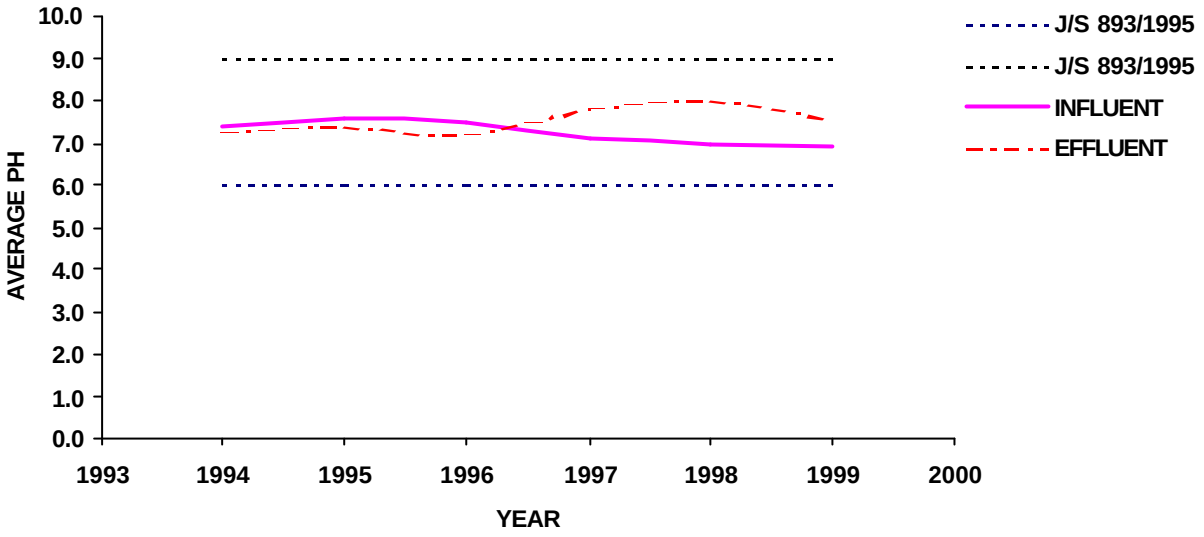
JARASH TDS

The Total Dissolved Solids (TDS) in the effluent from Jerash (east) are well within the limits specified in the Jordanian Standards. Note that the TDS levels in the influent are usually higher than that in the effluent.



JARASH TSS

Despite the Jerash (east) facility being relatively effective at removing suspended solids, the TSS level in the effluent is above the Jordanian Standard of 50 mg/l.



JARASH PH

The PH of the effluent is generally between 7.0 and 8.0, which is within the range (6.0 – 9.0) specified by the Jordanian Standards.

The data records for NO_3N (nitrate nitrogen), NH_4N (ammonia nitrogen), and PO_4P (phosphate) are relatively incomplete with either one or no records in any given year. The limited data that do exist suggest that NO_3N levels are trending upwards and are well above the standards, the NH_4N are more than double that of the standards, that PO_4P levels were trending upwards from 1994 to 1996 when they had reached about double the standard.

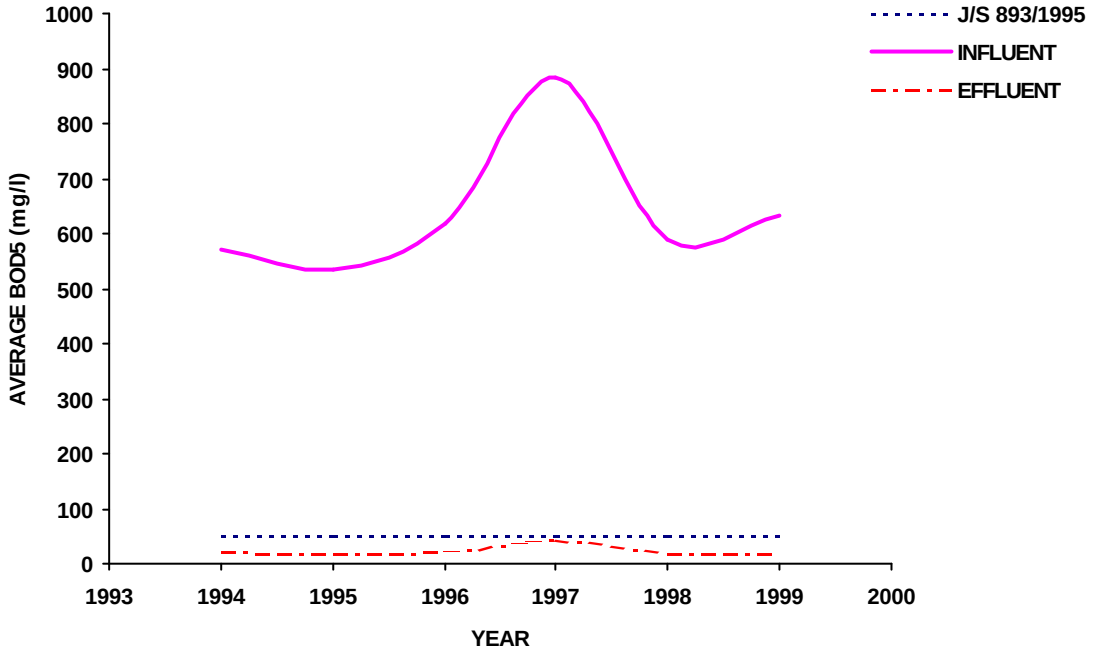
The Jordanian Standards for boron (B) in effluent discharges to wadis is 2-mg/l. The only Boron records for the Jerash (east) facility are for 1998, and these suggest that levels are extremely high at over 27-mg/l.

The limited data records for total fecal coliform count (TFCC) for Jerash (east) are erratic, however, they are above the standard.

ANNEX C

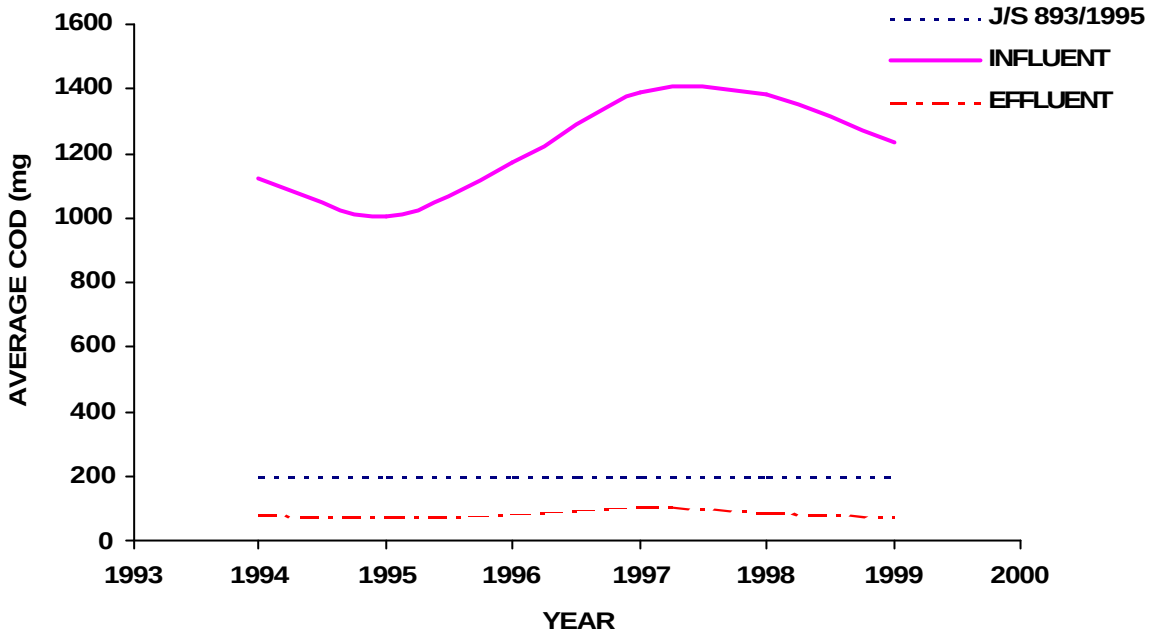
COMPARISON OF INFLUENT & EFFLUENT QUALITY AT ABU NUSEIR

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Abu Nuseir. The parameters monitored are BOD_5, COD, DO, TDS, TSS and PH. For each of these parameters, the measured values in the influent and the effluent at Abu Nuseir, along with the relevant Jordanian Standard were graphed for 1994 through 1999 and are shown below.



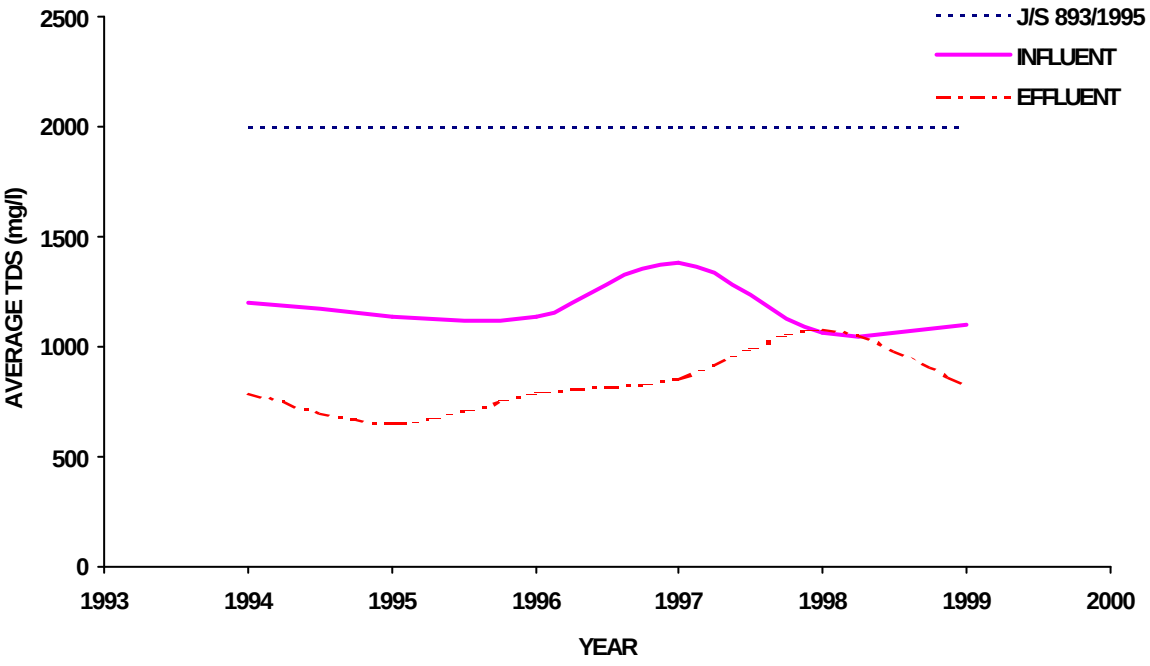
ABU NUSEIR BOD5

The Abu Nuseir facility is very effective at reducing the BOD_5, and for the last five years the level in the effluent has well within the Jordanian Standards.



ABU NUSEIR COD

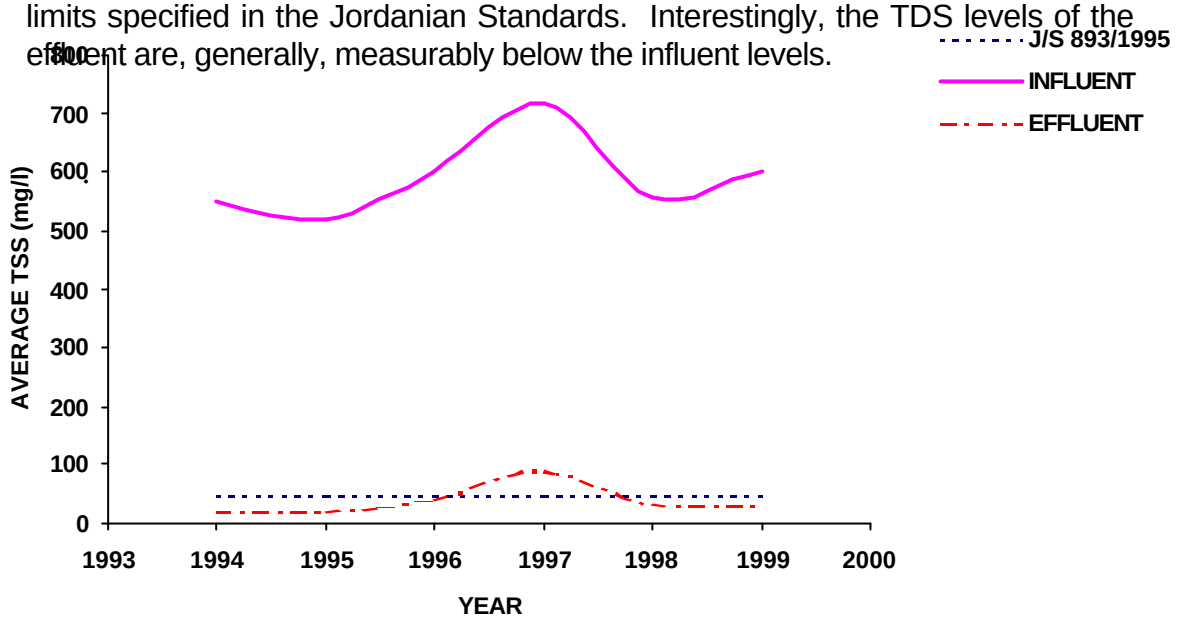
As with BOD_5, the Abu Nuseir facility is very effective at reducing the COD, and for the last five years the level in the effluent has been around half that of the relevant Jordanian Standard.



ABU NUSEIR TDS

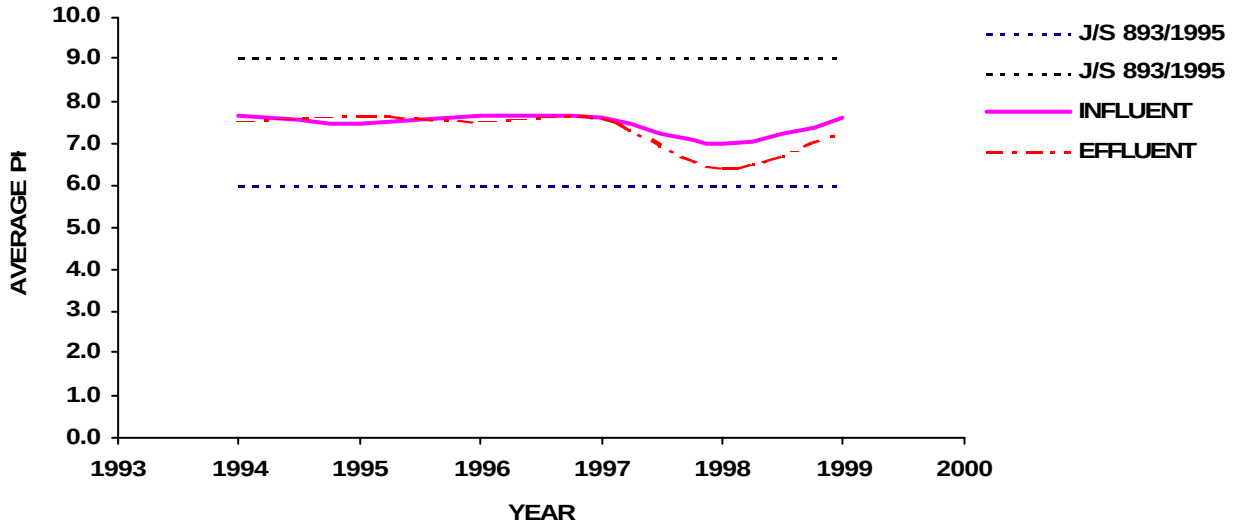
The Total Dissolved Solids (TDS) in the effluent from Abu Nusseir are well the

limits specified in the Jordanian Standards. Interestingly, the TDS levels of the effluent are, generally, measurably below the influent levels.



ABU NUSEIR TSS

The Abu Nuseir facility is effective at removing suspended solids, and has generally been in compliance with the relevant Jordanian Standard, except in 1997 when the TSS of the influent was relatively high.



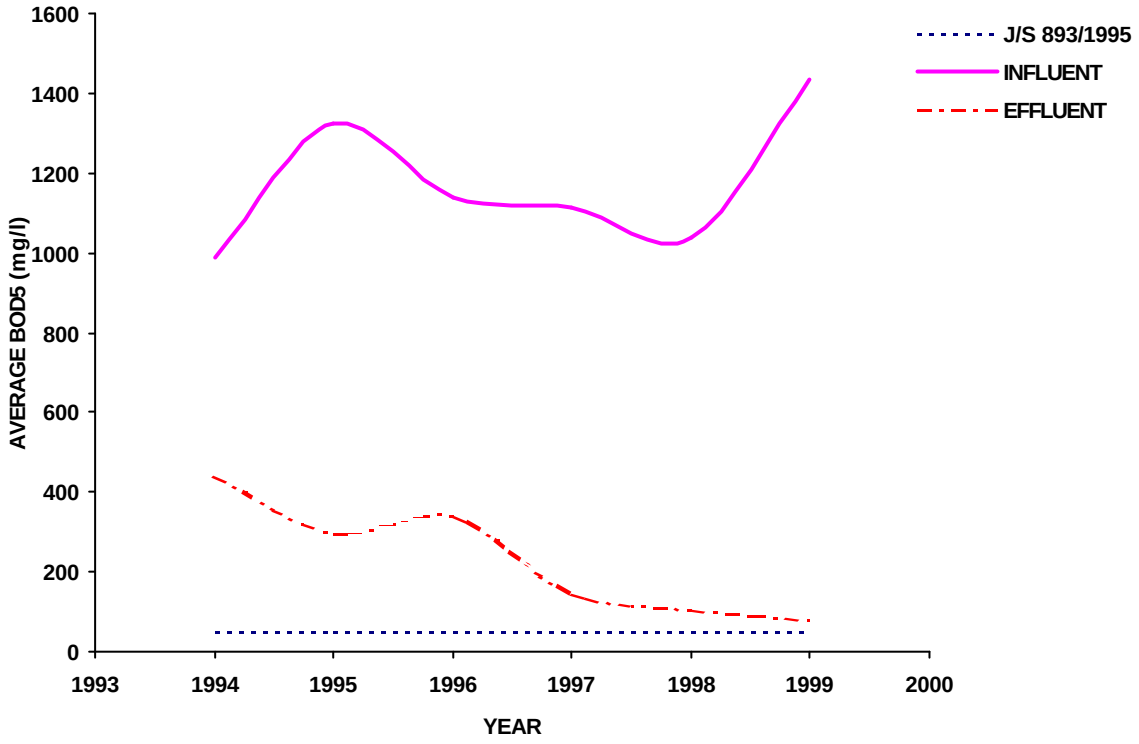
ABU NUSEIR PH

The PH of the effluent is generally between 6.0 and 8.0, which is within the range (6.0 – 9.0) specified by the Jordanian Standards.

ANNEX D

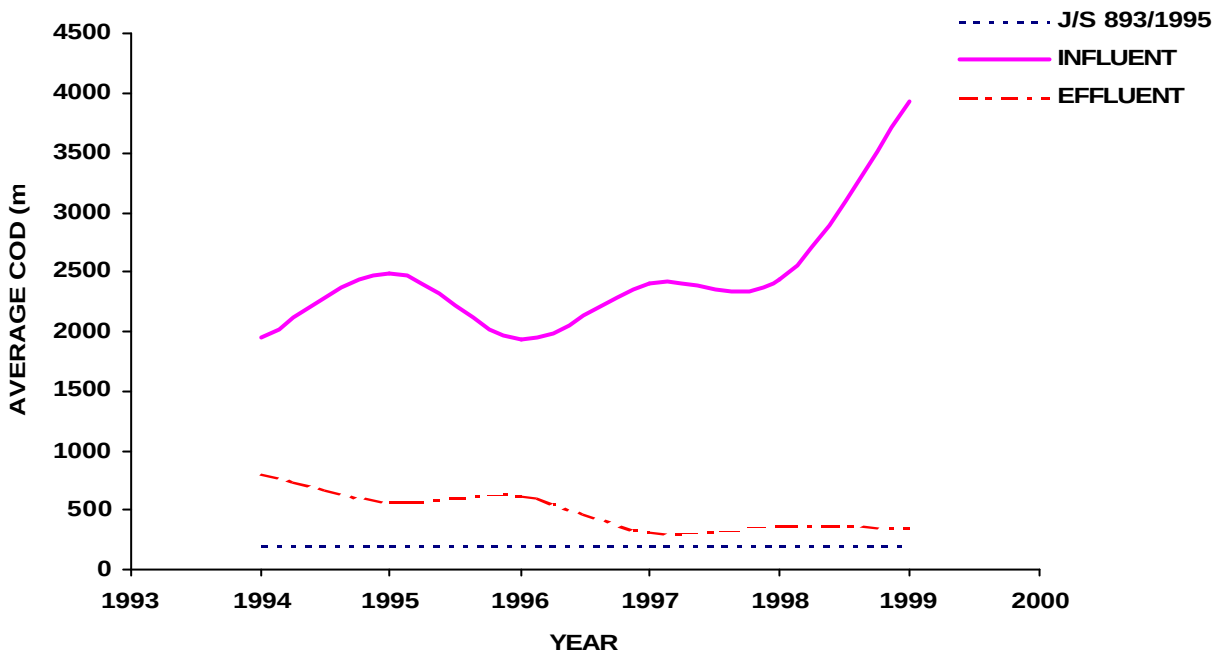
COMPARISON OF INFLUENT & EFFLUENT QUALITY AT BAQ'A

The Water Authority of Jordan (WAJ) samples influent and effluent water quality data (WAJ, 2000) at Baq'a. The parameters monitored are BOD_5, COD, TDS, TSS and PH. For each of these parameters, the measured values in the influent and the effluent at Baq'a, along with the relevant Jordanian Standard were graphed for 1994 through 1999 and are shown below.



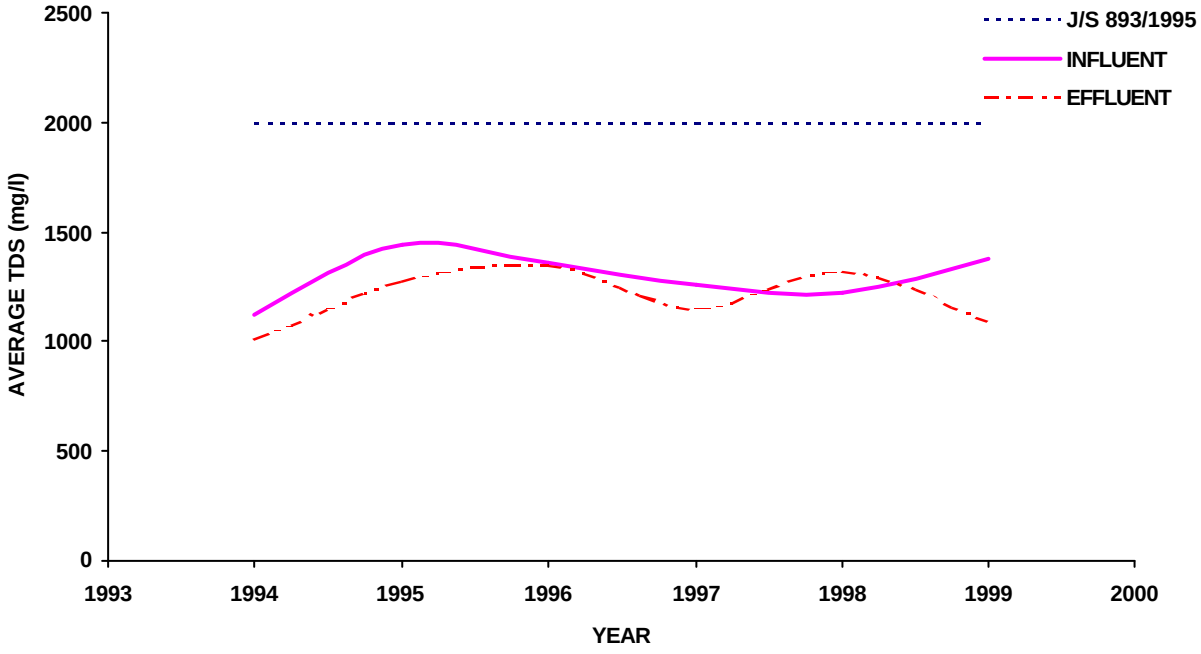
BAQA BOD5

Despite on going improvement in the effectiveness of reducing very high influent BOD_5 levels, the BOD_5 levels in the effluent from Baq'a remain significantly above the relevant Jordanian Standard.



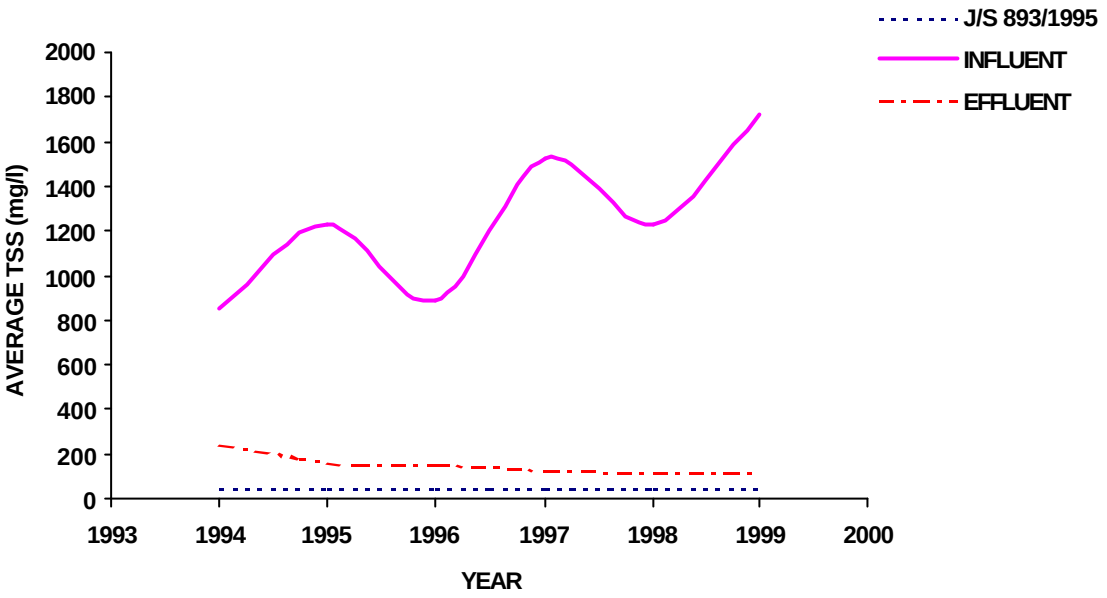
BAQA COD

Exhibiting a similar pattern to the BOD_5, the effectiveness of the Baq'a facility at reducing the COD has steadily improved, despite increasing COD levels in the influent. However, the COD levels in the effluent from Baq'a remain significantly above the relevant Jordanian Standard.



BAQA TDS

The Total Dissolved Solids (TDS) in the effluent from Baq'a are consistently well within the limits specified in the Jordanian Standards.



BAQA TSS

Despite the Baq'a facility being relatively effective at removing suspended solids, the TSS in the effluent is consistently much higher than the relevant Jordanian Standard.